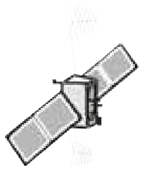
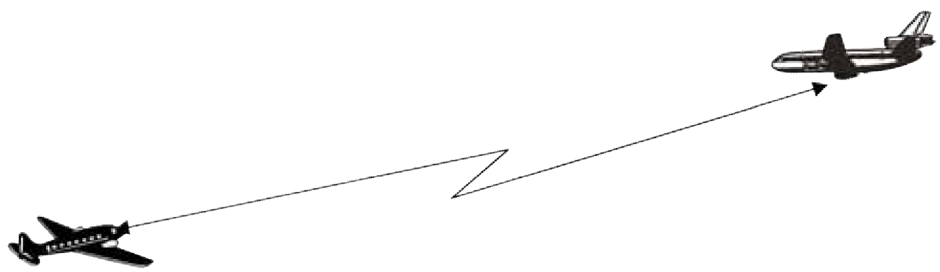


Safe Flight 21

FUNCTIONAL SPECIFICATION



May 15, 1999

US Department of Transportation
Federal Aviation Administration

Safe Flight 21

FUNCTIONAL SPECIFICATION

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Federal Aviation Administration

TABLE OF CONTENTS

List of Figures **Page**

Tables **Page**

1. INTRODUCTION AND SCOPE

This document provides the functional specification for the nine free flight operational enhancements identified by government and industry[1]. The Safe Flight 21 program is a government and industry cooperative effort to demonstrate and reduce the implementation risk of the set of free flight operational enhancement capabilities derived from evolving Communications, Navigation, and Surveillance (CNS), and Automation and Weather technologies. The SF 21 program replaces the Flight 2000 program, and incorporates user recommendations that efforts be focused on specific operational enhancements.

The underlying core concept of the free flight operational enhancement is the sharing of real-time traffic and weather information between the pilot and the controller in a manner that will improve safety and efficiency. Key new technologies for the program include the application of ADS-B (Automated Dependent Surveillance –Broadcast), Flight Information Services (FIS), Flight Information Services- Broadcast (FIS-B) Traffic Information Services (TIS), and their integration with enhanced pilot and controller information displays. The functional specification identifies the operational and functional requirements needed to implement the free flight operational enhancements in the NAS in a manner that is consistent with the ATS 2005 Operational Concept. In addition, this document provides the functional decomposition, functional interrelationships, functional description, data flow, and requirements traceability for each of the nine operational enhancements.

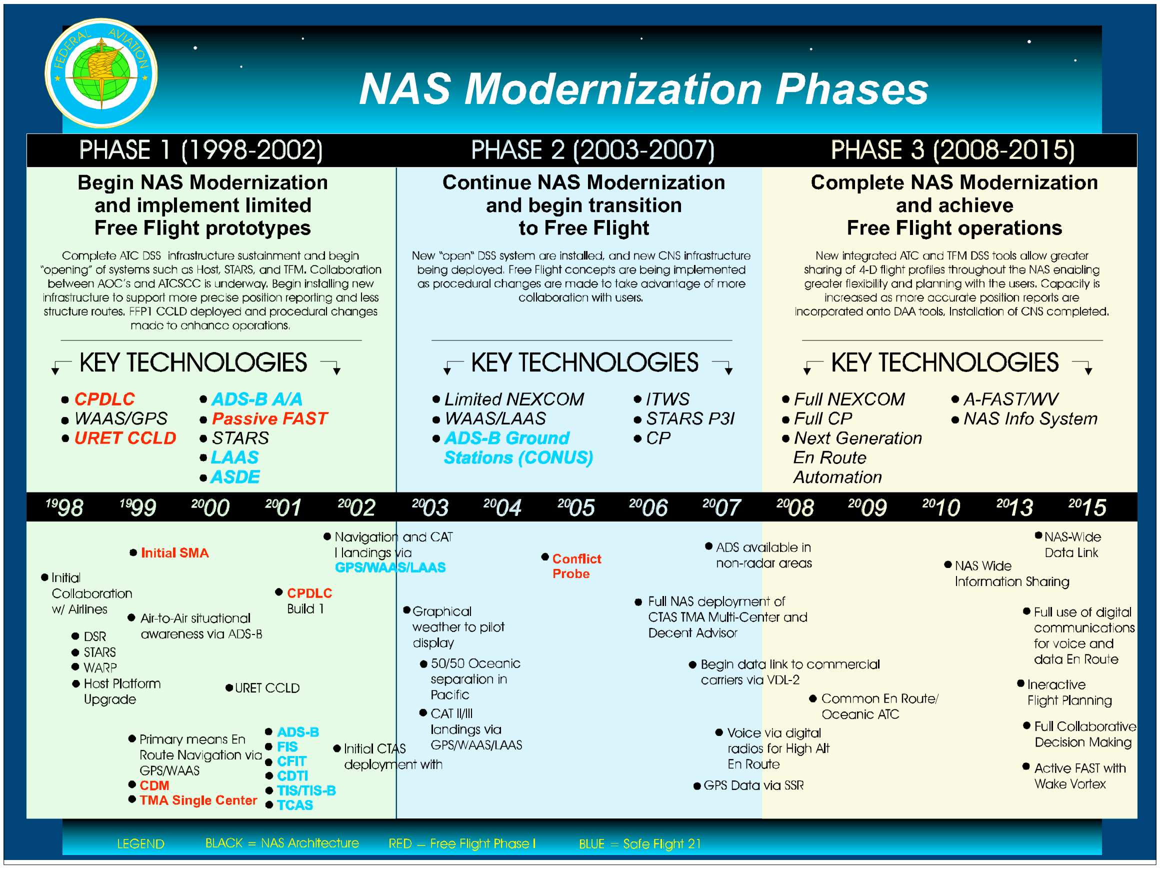
1.1 Safe Flight 21 Mission in the Free Flight Concept

The Functional Specification for the free flight operational enhancements is intended to support the introduction of newly emerging technologies into the NAS. Under the responsibility of the Safe Flight 21 program, new capabilities related to satellite and terrestrial CNS-technologies which have been verified and have assurance of minimum operational risk to users and service providers will be introduced into the NAS.

The NAS Architecture 4.0 presents a system description of the planned future NAS that is based on a joint satellite and radar surveillance concept. The end goal of Architecture 4.0 is to move closer toward a free flight operational capability. The NAS Modernization Phases, shown below, illustrates the transition from the current architecture to free flight capabilities.

The NAS Modernization Plan in Figure 1 covers the time period from 1998-2015 in three phases. Phase 1, 1998 through 2002; Phase 2, 2003 through 2007; and Phase 3, 2008 through 2015.

[1]RTCA Select Committee. Joint Government/Industry Roadmap for Free Flight Operational Enhancements. August 1998



Legend: Red systems represent Free Flight Phase1 deployment
Blue systems represent Safe Flight 21 deployment
Black systems are the NAS modernization baseline

FIGURE 1.1-1 NAS Modernization Plan

The transition to the future system described by Architecture 4.0 and the ATS 2005 CONOPS begins implementation of Free Flight Phase 1 (FFP1) technologies, and concurrently implementation of Safe Flight 21 nine operational enhancements. The NAS infrastructure will be upgraded with new equipment according to the modernization plan and the current systems will be maintained until new systems are deployed.

Success of timely transition depends on the Safe Flight 21 validation and risk reduction demonstrations of emerging CNS technologies. A timeline for the NAS modernization capabilities is presented in Figure 2. The blue color blocks represent systems that support Safe Flight 21 enhancements and illustrate when operational readiness for deployment is expected.

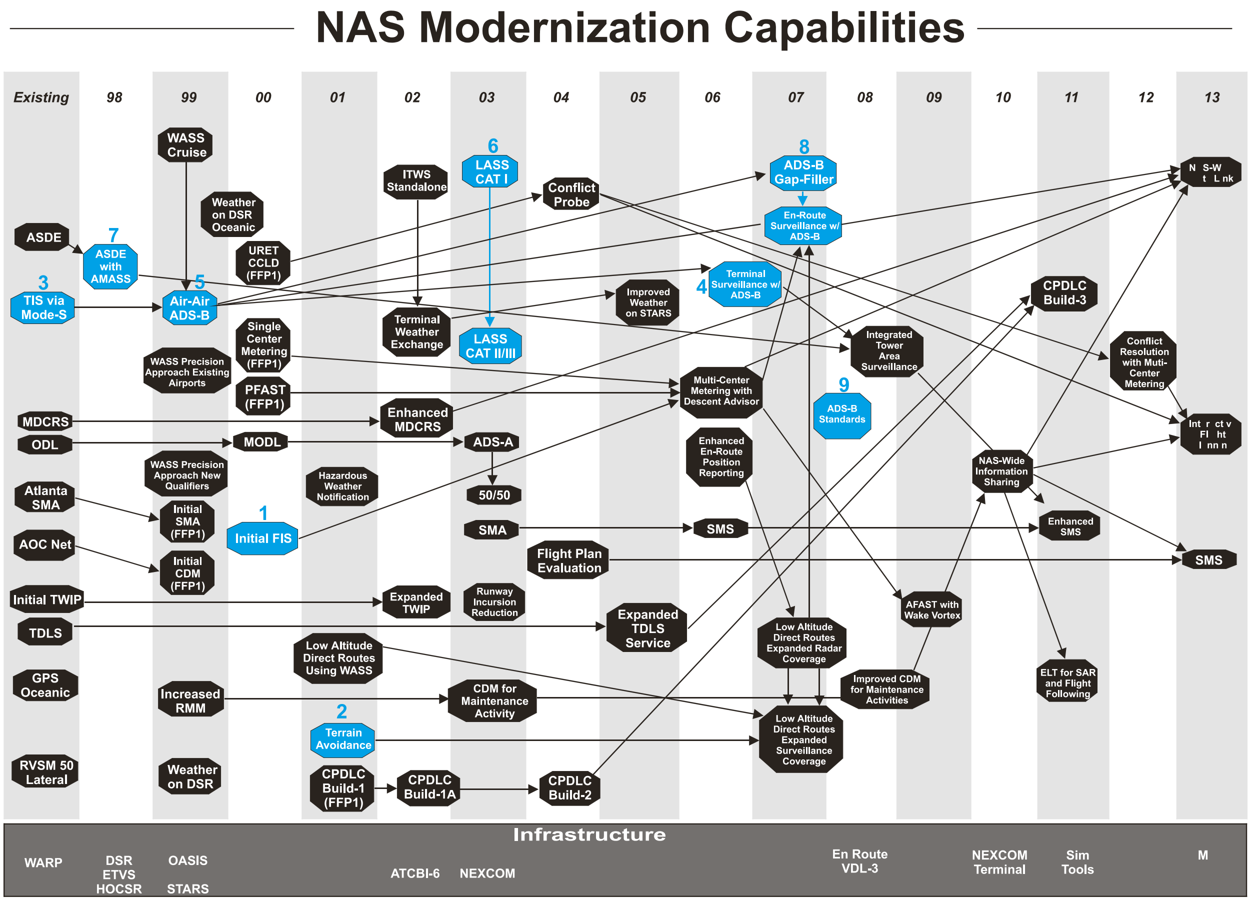


Figure 1.1-2 NAS Modernization Capabilities

1.2 Free Flight Operational Enhancements

1.2.1 Nine Operational Enhancements

The nine free flight operational enhancements are summarized as follows:

1. **Flight Information Service (FIS)** establishes a direct communications link to the cockpit for SUA status, Weather, Wind Shear, NOTAMs, and PIREPS information.

2. **Cost Effective CFIT Avoidance (CFIT)** is an on-board system that provides improved situation awareness to the pilot concerning terrain and obstacles to flight.

3. **Improved Terminal Operations in Low Visibility (LVTO)** is an on-board enhancement based on ADS-B, CDTI, and TIS that provides the pilot with increased awareness of surrounding air traffic.

4. **Enhanced Visual Operations and Situational Awareness (ESA)** improves visual operations and provides increased traffic awareness based on ADS-B, CDTI, TIS, and TIS-B capabilities.

5. **Enhanced Operations For En Route Air-To-Air (ERA/A)** is based on CDTI, ADS-B concept and provides the pilot with the capabilities for self-separation and station keeping at the discretion of the controller.

6. **Improved Surface Operations (S/AO)** is based on the use of the GPS/LAAS system to provide information on the location of all airport surface traffic on a moving map display to the pilot.

7. **Airport Surface Display for the Controller (ASD)** provides a display of all surface traffic with ID, position, and velocity based on the use of ADS-B.

8. **ADS-B for Surveillance in Non-Radar Airspace (ADS-B/NRA)** is an enhancement that deploys ADS-B Ground Stations for surveillance in the non-radar airspace based on ADS-Broadcast of aircraft ID, state and velocity.

9. **Establish ADS-B Based Separation Standards (ADS-B/SS)** is an enhancement that combines available ADS-B and radar target data to enhance automation performance and potentially reduce separation standards.

1.2.2 CNS Supporting Technologies

The following technologies are supporting the implementation of the nine free flight operational enhancements but are not considered part of the enhancements themselves:

ADS-B Automatic Dependent Surveillance-Broadcast is a system on an aircraft or surface vehicle that broadcasts identity, position, altitude, velocity and other information for use by other aircraft, surface vehicles and ground facilities. ADS-B air-to- air and air-to-ground technologies play a major role in realization of the free flight operational enhancements. This technology is recognized as dependent surveillance because it requires each aircraft or surface vehicle to determine its position (by means of the on-board navigation system) and to report that position (and other data) via the ADS-B data link.

GPS/WAAS: This technology will be used in the free flight operational enhancement demonstrations. GPS/WAAS is the preferred navigation source for ADS-B operations in many of the selected capabilities. It was recommended by Select Committee that development of GPS/WAAS occur independent of the free flight operational enhancements and risks associated with GPS/WAAS will be addressed by the IPT implementing that program

GPS/LAAS: – This technology will also be used in the free flight operational enhancement demonstrations. GPS/LAAS is the preferred navigational source for surface applications, including the airport moving map display. The Select Committee determined that the current “LAAS – Industry funded program” is on schedule and will develop LAAS technology and procedures prior to the planned free flight operational

Enhancements field demonstrations. The Committee recommended that the on-going LAAS implementation occur independent of the free flight operational enhancements program.

DATABASES: Several free flight operational enhancements include map and terrain database to assist the pilot in navigation and terrain avoidance. It is expected that these technologies will use GPS/WAAS and GPS/LAAS for current position inputs.

CDTI: The Cockpit Display Traffic Information shows the position of all nearby ADS-B-equipped aircraft. TIS and TIS-B aircraft may also be displayed on the CDTI. The pilot may use this display of nearby traffic as a reference for tactical maneuvering, self-separation, and station keeping. This capability will greatly enhance situational awareness in the cockpit. In domestic airspace, pilots are expected to use ADS-B air-to-air surveillance for situation awareness, and limited shared responsibility for separation. In oceanic airspace and in low-density en route airspace, ADS-B may be approved as a means for pilots to conduct in-trail climbs, descents and passing maneuvers.

TIS: Traffic Information Service, is a Mode S data link service that provides aircraft positions and automatic traffic advisories to pilots. TIS products were included in the free flight operational enhancements. Suitably equipped aircraft will be able to request and receive a display of nearby traffic. The relative range, bearing, and altitude (if known), and a "proximate" or "threat" classification of nearby aircraft will be displayed as an alert to the pilot. This service will help pilots "see and avoid" other aircraft. It uses ground-derived radar surveillance data and is intended to improve safety and efficiency of flight by providing an automatic display of nearby traffic and warnings of potentially threatening conditions. The source of TIS information is the file of aircraft tracks maintained by the ground Mode S sensor providing radar beacon coverage for a region of airspace. While TIS can provide information alerts only to Mode S equipped aircraft under surveillance, TIS has knowledge of all ATCRBS aircraft in coverage (and, potentially, of non-transponder-equipped aircraft if a primary radar's coverage is integrated with the Mode S sensor). TIS generates alerts, but does not provide resolution advisories.

TIS-B: Traffic Information Service-Broadcast service is similar to TIS surveillance information, but the method of delivery is different. TIS-B broadcasts the information on a suitable datalink rather than by Mode S sensor selective address capabilities. Instead of delivering individually tailor message during the ground radar antenna beam time (antenna dwell time) on the target, TIS-B is broadcasts information on all known targets using a different message format, frequency, and protocol.

TIS-B may utilize the Universal Access Transceiver (UAT)- 966 MHz or VDL Mode 4-VHFdata link. For details refer to System Description for the Universal Access Transceiver (UAT)[2] and System Description for VDL Mode 4[3].

[2] Mitre Corp. System Description for the Universal Access Transceiver (UAT). January 1999.
[3] Draft: System Description for VDL Mode 4. March 2, 1999.

TCAS II and IV: Traffic Alert Collision Avoidance System II and VI may be combined into a single Hybrid system, this means to have both systems in one by adding to ADS-B avionics of passive receiver and squitter capability also an active interrogation capability for range measurement. Both of these systems provide alert and threat resolution concerning nearby aircraft, but they differ in the design.

TCAS II receives Mode S (56 bit) random short squitter with an aircraft identity which provides approximate directional information to the squittering aircraft. By receiving squitters on a sectored antenna (four to six sectors) a rough azimuth angel (8 to 11 degrees) is determined. To obtain the range to the squittering aircraft, TCAS II uses a 1030 MHz on-board transmitter to interrogate the aircraft and compute the range based on return signal arrival time. Coverage range is from 20 to 30 nautical miles.

TCAS IV passively listens to ADS-B extended squitter (112 bits long) transmissions by the aircraft avionics. The squitter message contains position information, velocity and intent. Decoded information is sufficient to have a complete aircraft surveillance information. .

CPDLC – This technology is not included in free flight operational enhancements program. However, the datalink media and cockpit displays selected for CPDLC will be considered in determining the Free Flight Operational Enhancements avionics requirements. This will ensure the radio and pilot displays developed as a result of the Free Flight Operational Enhancement program will be able to accommodate CPDLC from a CNS integration perspective.

NEXCOM: – This technology is not included in the free flight operational enhancements program. However, as with the case of CPDLC, adoption of NEXCOM technology is expected to simplify integration with other avionics systems, and may reduce development time, risk and cost.

VDL Mode 4 – **Self-organizing Time Division Multiple Access (STDMA**): It is an ATN compliant communications system that can provide both broadcast and point-to-point service. The broadcast service may provide position information. It can also support a range of other applications, which use the ATN-compliant or specific service function of VDL Mode 4. This datalink is being evaluated for the application to the nine operational enhancements of SF 21 program.

UAT – Universal Access Transponder: It is a system for evaluating multipurpose broadcast data link operating on a single wideband channel. The goal of the UAT project is to demonstrate this multipurpose broadcast data link architecture through laboratory and flight testing for use in SF 21 program.

1.3 Functional Specification Development Process

The process illustrated in Figure 1.3-1 is used to develop the functional requirements and specification for each of the nine Safe Flight 21 operational enhancements. The development process begins with the derivation of the operational requirements capabilities for the nine

Operational Enhancements contained in the ATS 2005 CONOPS and Joint Industry Road Map for Free Flight Operational Enhancements respectively. The resulting operational requirements for each of the proposed enhancements are used as the basis for the development of a set of functional requirements for each enhancement. These functional requirements are used to develop the detailed functional specification for each of the proposed ATC enhancements.

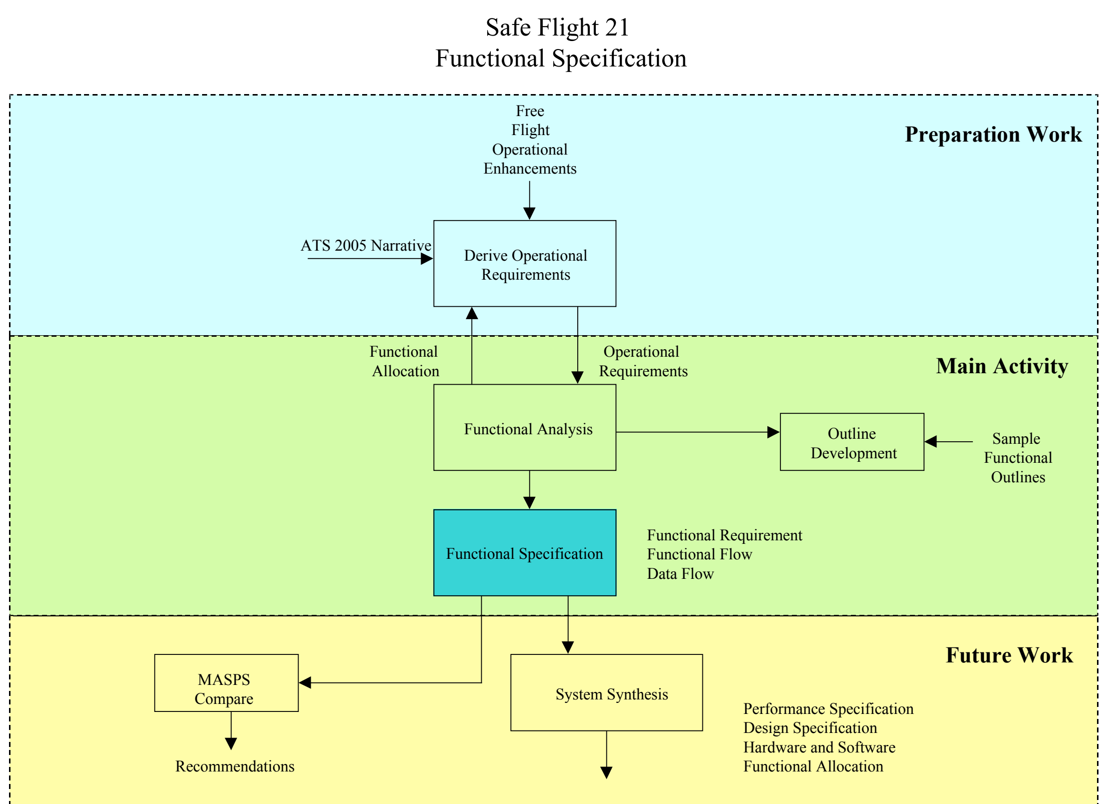


Figure 1.3-1 Functional Specification Development Process

1.3.1 Operational Requirements

The objective of this report is to develop the functional requirements and specifications for each of the nine ATC operational enhancements that form the basis of the Safe Flight 21-program. The process begins with the description of the nine operational enhancements contained in the Joint Government/Industry Roadmap for Free Flight Operational Enhancements. These descriptions are analyzed to determine the top-level functions necessary for their implementation. From these top-level functions, the ATS 2005 CONOPS Narrative are analyzed to determine those operational requirements that apply to each of the nine operational enhancements. Traceablility among the nine operational enhancements, the ATS 2005 CONOPS Narrative and the ATS 2005 Addendum will be maintained. The operational requirements for the Safe Flight 21 Operational Enhancements will be provided using the NASA AAAT, which contains the Level I and Level II operational needs as derived from the ATS 2005 Operational Concept Addendum, respectively.

1.3.2 Functional Requirements

The functional requirements for each of the nine operational enhancements are determined from the enhancements' capabilities and the derived operational requirements. The functional requirements are formulated by decomposing the top-level requirements and capabilities. Traceability among the functional requirements, the operational requirements, and the ATS 2005 Narrative are maintained.

1.3.3 Functional Specification

The functional specification is developed from the functional requirements derived for the nine operational enhancements. The functional specification consists of a functional block diagram depicting the functional inter-relationship and data flow among the functions and a narrative description for each identified function. The level of detail for the functional specification corresponds to the level of detail derived in the derived functional requirements.

1.3.4 Relationship to the ADS-B Minimum Aviation System Performance Standards (MASPS)

The ADS-B MASPS were developed prior to the development of the detailed functional requirements and specifications for the Safe Flight 21 Operational Enhancements contained in this functional specification. The MASPS states (see MASPS paragraph 2.1) that the ADS-B is designed to support numerous applications which are not currently designed, implemented, or certified. It further states that rather than wait for the designs which would delay ADS-B for years, a decision was made to develop reasonable requirements based on operational judgements and initial analysis for a number of stressful applications. It is assumed by the MASPS that more stringent requirements are accounted for by the required expandability specified in Section 2.1.1.3 of the MASPS.

It is, therefore, necessary that the ADS-B MASPS be re-examined to determine the extent to which they satisfy the now available SF-21 operational enhancement functional specification. This re-examination must also be repeated once the performance specification for the SF-21 operational enhancements is developed. In summary, the ADS-B MASPS are developed to support the requirements and needed capabilities of future applications and as such, be periodically re-visited to keep them current in the evolving architecture.

1.4 Document Organization

Chapter 1 provides an overview of the functional specification development process and of the Free Flight Operational Enhancements. Chapter 2 lists applicable documents used for the development of the functional specification. Chapter 3 presents the system concepts and capabilities for each enhancement, the functional requirements, the functional design and data flow, human factor consideration and traceability matrices for each of the nine operational enhancements. Chapter 4 provides a list of acronyms and abbreviations and definitions.

2. APPLICABLE DOCUMENTS

2.1 Government Documents

1. FAA, National Airspace System Architecture, Version 4.0, January 1999.

2. FAA, ATS Concept of Operations for the National Airspace System in 2005, Narrative, September 20, 1997.

3. FAA, Air Traffic Services Concept of Operations for the National Airspace System in 2005, Addendum 1, July 23, 1998.

4. DOT/FAA-E-2900A Specification, Integrated Terminal Weather System (ITWAS), April 7, 1998.

2.2 Non-Government Documents

1. RTCA Select Committee, Joint Government/Industry Roadmap for Free Flight Operational Enhancements, August 1998.

2. RTCA Special Committee – 186, Operations Concepts for Cockpit Display of Traffic Information (CDTI) Applications, Draft 1, January 6, 1999.

3. RTCA Select Committee, System Description for VDL Mode 4, Draft, 2 March 1999.

4. RTCA Free Flight Select Committee, System Description for the Universal Access Transceiver (UAT), January 1999.

5. MIT/LL, Reconfigurable ADS-B Interrogator/Receiver Station (RAIRS) Report.

6. RTCA, Minimum Aviation System Performance Standards for Automatic Dependent Surveillance – Broadcast (ADS-B), Document No. RTCA/DO-242 Prepared by SC-186, February 19, 1998.

3. REQUIREMENTS

This chapter provides the functional specification for each of the nine operational enhancements. Figure 3-1 illustrates the applicability of each of the nine operational enhancements to the phase of flight in the NAS.

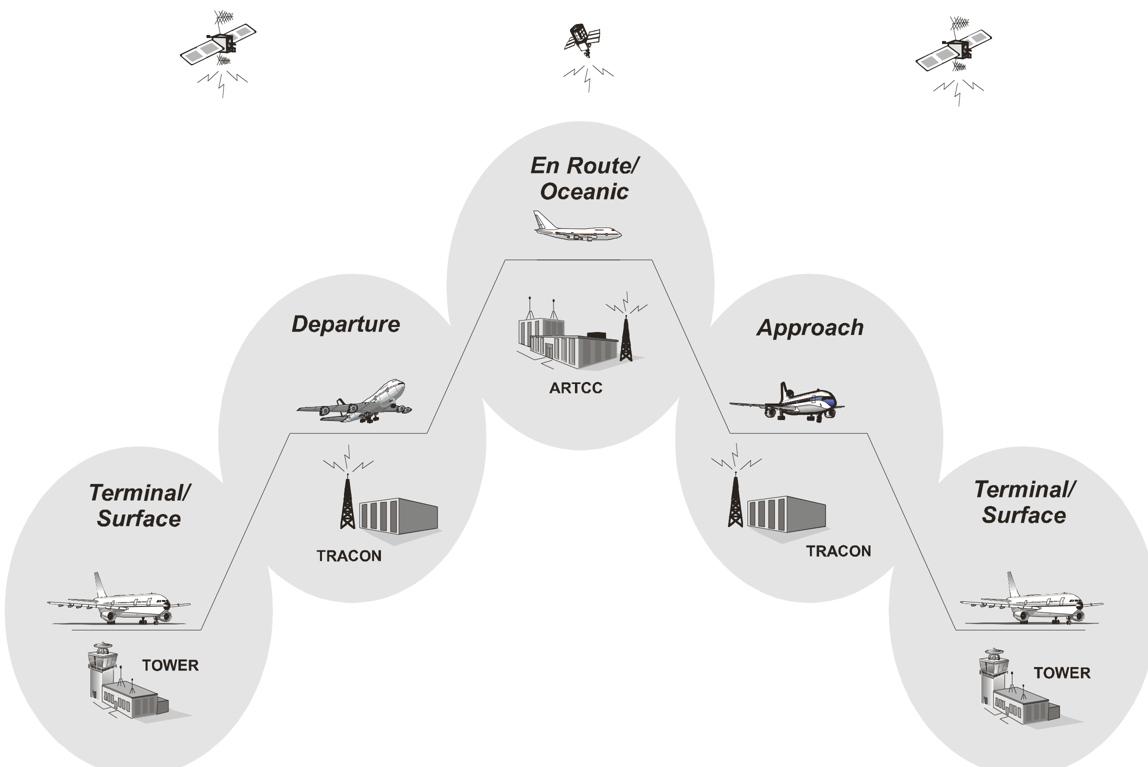


Figure 3-1 Operational Enhancements NAS Domains

Each subsection consists of a description of the system concept, the functional requirements for each of the major ATC functions and the functional design including the functional and data flow diagrams and interface requirements.

3.1 Flight Information Services (FIS) Functional Specification

The functional specification for the FIS consists of a detailed description of the FIS system concept, a presentation of the FIS functional requirements for each of the major ATC functions (i.e., Communications, Navigation, Surveillance, Weather, Automation, and Maintenance and Operations), and an elaboration of the FIS functional design including functional flow diagrams and interface requirements.

3.1.1 FIS System Concept

The FIS concept consists of a definition of the operational concept, the capabilities, and the expected benefits. Within the operational concept, the FIS mission and modes of operation are also defined. Figure 3.1.1-1 illustrates the FIS concept and shows that it consists primarily of data collection and processing, and communications functions. In essence, information that will enhance a pilot's awareness of the weather, airspace, and NAS status that could impact flights in a given geographic area is broadcast to pilots. Aircraft specific warnings of hazardous weather such as wind shear/micro-burst activity may also be sent directly to pilots via a discrete data link. FIS does not perform any meteorological observations or surveillance of aircraft but rather uses the information made available from other sources. One of the primary sources of aircraft, weather and aeronautical data is expected to be the NAS Wide Information System (NAS-WIS).

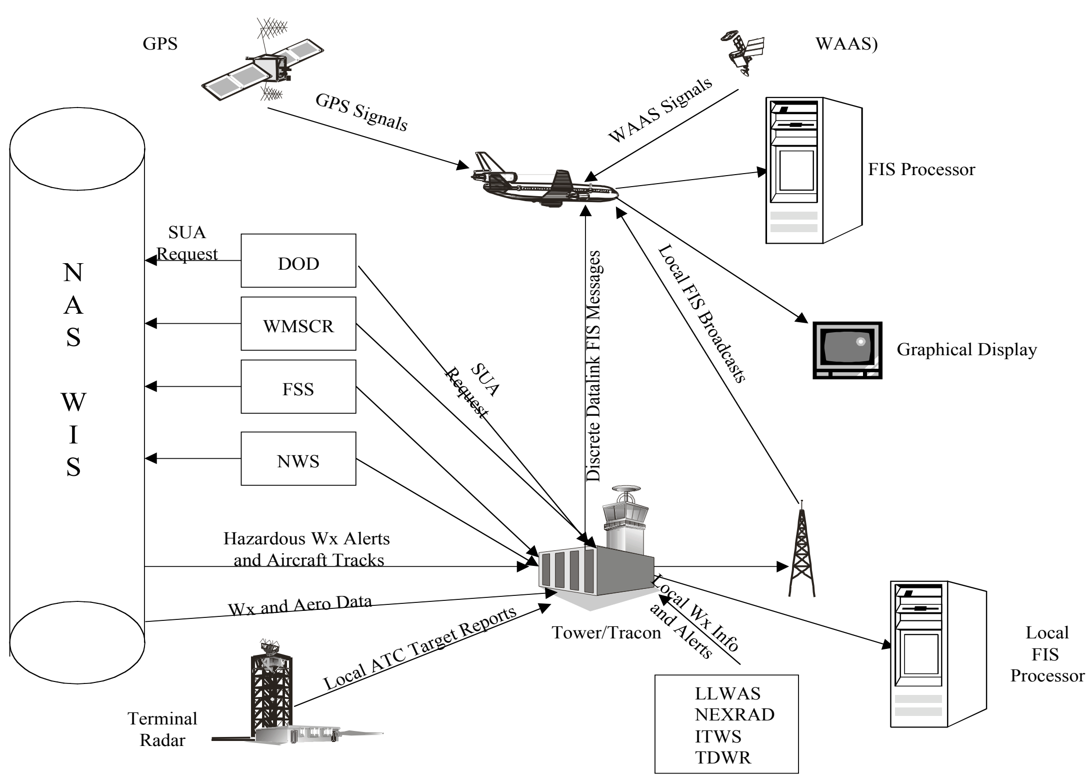


Figure 3.1.1-1: FIS System Concept

3.1.1.1 FIS Operational Concept

Flight Information Services (FIS) is non-control advisory information service needed by pilots to operate more safely and efficiently. FIS includes aeronautical information, current and forecasted weather, weather hazard information and Special User Airspace (SUA) status, necessary for flight planning and for continued safe flight. FIS uses a ground based data server and data links to provide the variety of information. Pilots currently receive weather information or special user airspace information through voice communications with ATC. FIS will provide increased availability of flight services, timeliness and quality of data on weather and system status, access to airspace and a reduction in flight times and flight distances.

3.1.1.1.1 Mission

There is a significant amount of data in the National Airspace System that, if the pilot could have access to it in the cockpit, would make the flight safer or more cost effective through improved situational awareness. Without this information the pilot faces uncertain weather hazards and other operational inefficiencies. Thus, the mission of the FIS system can be stated as:

Improve flight safety and efficiency through increased situational awareness

3.1.1.1.2 Modes of Operation

There are two basic modes of operation for the FIS:

- Broadcast Mode,
- Discrete Message Mode

In the broadcast mode, a common frequency is used to broadcast the FIS messages to all pilots within reception range of the FIS transmitter. In the discrete message mode, aircraft specific FIS messages such as wind-shear alerts are generated and transmitted to specific aircraft using a discrete address data link messaging capability.

3.1.1.2 FIS Capabilities

The implementation of FIS provides the following operational capabilities:

- In flight updates on status of SUAs of interest
- Flight information to the cockpit including SUA status, graphical weather, NOTAMs and PIREPS
- Pilots receive current and forecasted weather for airports (e.g. ATIS, RVR, wind shear/micro-burst alerts, braking action) of interest and along the route in the cockpit
- Integrated terminal area weather broadcasts with automatic updates for airborne aircraft
- Up link of real time wind shear information to the aircraft
- Collection and dissemination of textual and graphic hazardous weather information to pilots, including WARP weather products

3.1.1.3 FIS Benefits

The FIS is expected to produce the following benefits:
- Increase availability of flight services
- Increase timeliness and quality of data on weather and system status
- Increase access to airspace
- Reduce flight times and distances flown

3.1.2 FIS Functional Requirements

The functional requirements for FIS have been developed by first considering the FIS capabilities and then determining the relevant operational needs as stated in the ATS 2005 CONOPS Narrative. The operational needs were then analyzed to determine the ATC functions that were required to satisfy the need. These FIS operational requirements are presented as requirements traceability matrices in Section 3.1.3.3 and are summarized for each of the major ATC functions in the following paragraphs.

3.1.2.1 Communications

FIS is a communications intensive operational enhancement that uses both broadcast mode and discrete mode communications. An analysis of the detailed communications requirements contained in the requirement traceability matrix (Section 3.1.3.3) results in the following set of communications functional requirements:

1. The FIS shall communicate with the NAS-WIS to obtain the information necessary to provide both broadcast and discrete FIS messages. When necessary, the NAS-WIS information shall be supplemented by communications with local facilities including ITWS, local ATC Facilities, and local weather and aeronautical information systems.
2. The information to be obtained from external sources via appropriate communications media shall be timely and consistent across the NAS and shall include flight specific data, aeronautical information, ATIS and other weather information, hazardous weather alerts for wind shear, gust fronts, and micro-bursts, SUA status; airspace configuration and route structure and current and forecast weather.
3. Communications between the FIS ground element and the aircraft shall be accomplished by broadcasting the FIS broadcast messages to aircraft in the FIS service area. Through the use of voice synthesis technology, ATIS messages are no longer manually recorded by service providers and these messages shall be transmitted digitally.
4. Discrete communications between the FIS ground element and the aircraft shall be accomplished using a discrete addressing data link for delivery of FIS messages to specific aircraft. Complementary digital communications systems enable datalinking of routine communications and FIS discrete messages. PIREPS shall be provided directly to the NAS-WIS rather than to the FIS.
5. Communications between the FIS ground element, the service provider, NAS-WIS, and local ATC systems and facilities shall be accomplished using appropriate Ground/Ground communications links including landlines, microwave, NADIN and the like.

3.1.2.2 Navigation

Navigation information is required for FIS to display the weather and hazard information relative to the aircraft. Thus, the position of won aircraft is required for FIS to properly display weather and aeronautical information in the cockpit. This leads to the following requirement:

1. The FIS system shall receive its navigational position from GPS, when available.
2. The navigational position information shall be able to accommodate WAAS and LAAS satellite information, when available.
3. If GPS is not available, the aircraft shall use an appropriate area navigation instrument to provide an input to the FIS processor.

3.1.2.3 Surveillance

If NAS-WIS interface is not available, interface with the surveillance track file is needed to develop the aircraft specific hazard alerts. FIS does not have any direct functional requirement in the aircraft surveillance area since it obtains all aircraft surveillance data from external sources. Direct interface with aircraft surveillance systems or the ground based surveillance systems is not required for the FIS if NAS-WIS interface is available.

3.1.2.4 Weather

FIS does not have any direct functional requirement in the weather area since it obtains all weather data from external sources. The FIS may initially (i.e., prior to NAS WIS availability) however be required to interface directly with weather radar systems, weather observation systems, and integrated systems to detect and predict hazardous weather. In this instance, integration and processing of this information will be necessary.

3.1.2.5 Automation

The FIS is an automation intensive function. The type of automation required for FIS consists of data collection, processing, formatting, and display rather than decision support tool functions. It is expected that the FIS can be fully automated and does not require a man-in-the-loop. However some form of message validity checking must be implemented as part of the FIS system. The FIS automation requirements are:

1. The FIS shall have automatic access to the NAS-WIS and all other essential sources of data in order to obtain timely and consistent data. The automatic data collection function shall, at a minimum, include collection of: flight specific data; aeronautical information; ATIS and other weather information, hazardous weather alerts for wind shear, gust fronts, and micro-bursts; SUA status; airspace configuration and route structure; and, current and forecast weather.
2. The FIS shall automatically collect and process all aircraft, weather and aeronautical information necessary to generate FIS broadcast and discrete messages
3. The FIS shall automatically format all FIS broadcast and discrete message types.

4. The FIS shall automatically initiate the broadcast of all FIS broadcast messages according to a prescribed schedule and on an exception basis for emergency messages such as hazardous weather warnings.
5. The FIS ground element shall automatically provide a feed to the Controller Display generator and shall accept inputs from the controller via the controller display
6. The FIS shall automatically correlate aircraft position with the location of hazardous weather, wind shear, gust fronts, and microburst activity. Specific hazardous weather messages shall be generated and formatted for specific aircraft based on this correlation. The FIS shall interface with an appropriate data link message processor to accomplish delivery of these discrete messages to a specific aircraft.
7. The FIS message processor on-board an aircraft may be integrated with other data link processing equipment including the flight management computer or the ATN equipment. This airborne FIS processor shall automatically process and format the FIS messages for display to the pilot.
8. The FIS shall not respond to inputs from the pilot via the pilot's graphical display or through the flight management computer, or any other device interfaced with the FIS message processor other than to initiate or to terminate the display of FIS messages.
9. PIREPS shall be automatically generated on-board an aircraft external to the FIS equipment and shall be forwarded to the NAS-WIS and other appropriate facilities. The on-board, automatic PIREP system shall not directly interact with the FIS system.
10. The FIS shall automatically provide messages to the service provider in such a format as to make optimal use of the service provider's advanced display capabilities.
11. The FIS shall provide an automatic method for verification and validation of the FIS messages.

3.1.2.6 Operations and Maintenance

1. The FIS shall automatically monitor the status of the NAS-WIS and other external systems with which it is interfaced. It shall automatically reject information from an external system that is not operational.
2. The FIS shall automatically monitor its own operational status and shall report this status to the NAS-WIS and the local ATC facility. In the event that the FIS is non-operational, a broadcast message shall be generated indicating this status.
3. The FIS ground element shall be equipped with remote maintenance monitoring capabilities.

3.1.3 FIS Functional Design

This section presents the functional design for the FIS that will satisfy the requirements and provide the capabilities previously described. In addition, the FIS data flow will also be discussed as part of the overall functional design. To begin, consider the functional flow chart for the FIS functional design presented as Figure 3.1.3-1.

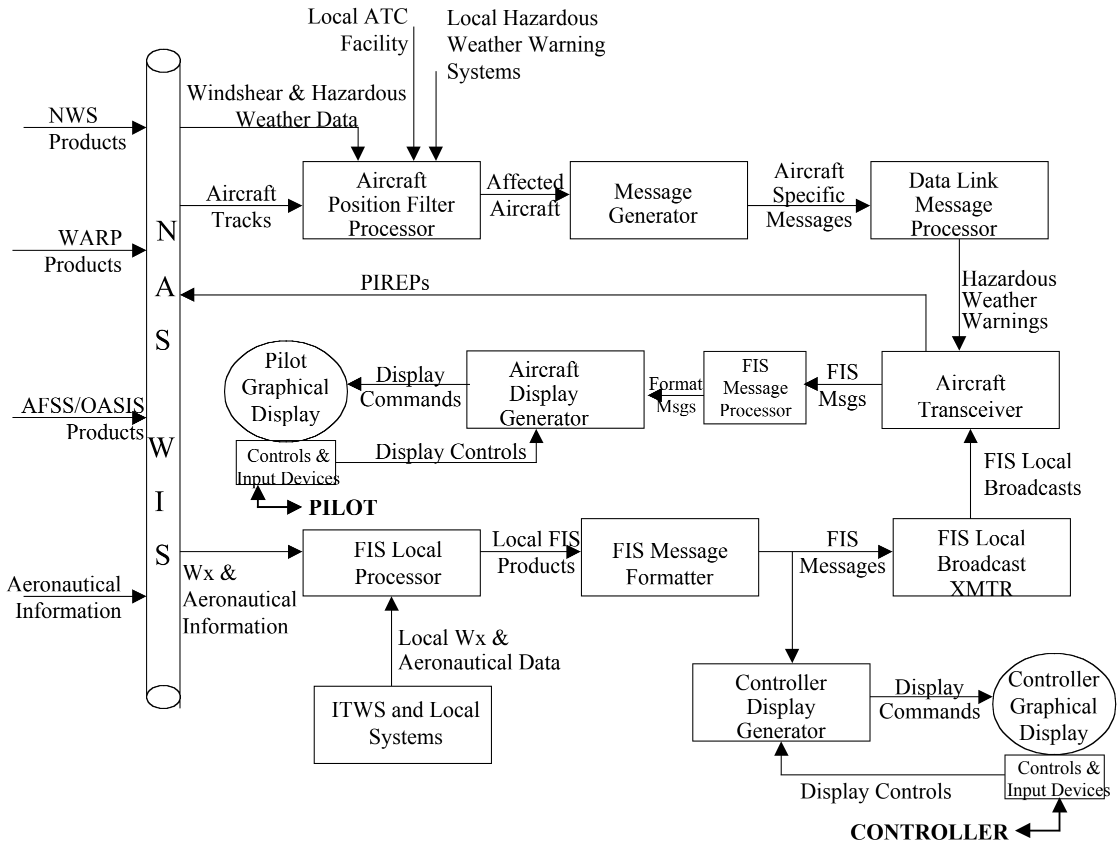


Figure 3.1.3-1 FIS Functional Block Diagram

The functional design for the FIS begins with the major assumption that the NAS Wide Information System (NAS-WIS) is in place and operational. If this assumption is not valid, then the functions performed by the NAS-WIS must be incorporated into the design of the FIS; when the NAS-WIS becomes operational this portion of the design would be discarded. The specific functions in question are those associated with the raw aeronautical, weather, and aircraft position data collection and processing that will be performed by the NAS-WIS.

The ATS 2005 CONOPS identifies and defines the NAS-WIS and provides detailed information concerning its capabilities including:

> *"A NAS-wide information system distributes timely and consistent information across the NAS, for both user and service provider planning. This information system serves as an avenue for a greater exchange of electronic data and information between users and service providers. The system contains the following information:*
>
> - *Static data such as maps, charts, airport facility guides, and published Notices to Airmen (NOTAMs)*
> - *Dynamic information such as current and forecast weather, radar summaries, hazardous condition warnings, information on updated airport and airspace capacity constraints, and special use airspace (SUA) schedules.*

- *Flight information on each flight including the filed flight profile and all amendments, first movement of the aircraft, wheels-up, position data in flight, touchdown time, gate or parking assignment, and engine shutdown.*
- *Schedule information which is updated throughout the day to reflect changes in carrier operations." ATS 2005 CONOPS Narrative*

3.1.3.1 System Functional Relationships

FIS has two basic modes of operation: broadcast mode; and, discrete mode. First, consider a detailed examination of the broadcast mode of operation. The FIS Local processor interfaces directly with the NAS-WIS (see Figure 3.1.3-1) and extracts all aeronautical and weather information of interest including information from the AFSS/OASIS, WARP, and NWS Products. Ideally, ITWIS products would also be available on the NAS-WIS but if not, a separate interface may be needed for those terminal areas that have ITWS capability. In any event, the FIS Local Processor develops the products needed to achieve the stated FIS capabilities and to satisfy the associated operational requirements. These products include:

- SUA status
- Graphical weather products
- NOTAMs
- PIREPS
- ATIS
- RVR
- Wind shear alerts
- Micro-burst alerts
- Braking action
- Terminal area weather broadcasts
- Textual and graphic hazardous weather information

These products and others yet to be determined are then passed to the FIS Message Formatter where they are prepared for dissemination to pilots and to controllers. Formatted messages are provided to controllers via the Display Generator which provides display commands to the Controller Graphical Display. Aircraft messages are passed to the FIS Local Broadcast Transmitter where they are broadcast in a timely fashion to aircraft in the local vicinity. This transceiver also provides PIREPS to the NAS-WIS using voice reports or possibly automated PIREPS such as winds aloft from the aircraft's Flight Management System. Once received by a specific aircraft, the FIS Messages are then prepared for either textual or graphic display by the Aircraft FIS Message Processor and then passed to the Display Generator which provides the display commands to the Pilot Graphical Display. The pilot may interface with this display to select or deselect specific FIS messages.

Next, consider the flight specific discrete mode of operation. In this case, the FIS must obtain the positions and ID of aircraft in the local area and specifically those on approach. The Aircraft Position Filter Processor examines the positions of all aircraft relative to the wind shear/micro-burst information that is available from the NAS-WIS or from local systems such as ITWIS, LLWAS, TDWR and the like. Based on this correlation, all potentially affected aircraft are identified and this information is passed to the discrete message generator. This function prepares aircraft specific messages and alerts and provides these to a Data Link Processor, which then transmits messages and warnings to each of the involved aircraft. Only those aircraft to which the messages are sent receive these messages. The messages are then processed by the Onboard FIS Message Processor and forwarded to the Aircraft Display Generator for presentation to the pilot via the Pilot Graphical Display.

3.1.3.2 Interface Requirements

Given the existence of the NAS-WIS, the FIS will interface with this system and will collect the information needed for the local area being served. Examining the FIS functional design illustrated in Figure 3.1.3-1 one observes that there are two major inputs to the FIS from the NAS-WIS. The first is aeronautical and weather data and the second is aircraft tracks from the local TRACON. The first interfaces, i.e., aeronautical and weather information, is needed to provide the following information broadcast capabilities:

- In flight updates on status of SUAs of interest
- FIS to the cockpit graphical weather, NOTAMs and PIREPS
- Pilots receive in the cockpit current and forecasted weather for airports (e.g. ATIS, RVR, wind shear/micro-burst alerts, braking action) of interest and along the route of flight via data link
- Integrated terminal area weather broadcasts with automatic updates for airborne aircraft
- Collection and dissemination by FIS processor of textual and graphic hazardous weather information to pilots, including WARP weather products

Note that interfaces with local weather and aeronautical information systems may be necessary to supplement NAS-WIS data or to replace it if NAS-WIS is not available.

Note that the FIS will provide PIREPs to the NAS-WIS as part of this function, which will then become available to all aircraft. Local interfaces with weather systems including ITWS, AWOS, LLWAS and hazardous weather warning systems are also part of the FIS functional design.

The second NAS-WIS interface is needed to provide the capability for flight specific up link of real time wind shear hazardous weather information to the aircraft. This information can also be obtained from the local Air Traffic Control facility (e.g., ARTCC, TRACON) that coincides with the FIS service area. This discrete message capability differs from the others in that it is flight specific although general broadcast warnings can also be provided as part of the broadcast capabilities identified above. This second interface is needed since wind-shear information is very dynamic and may be aircraft specific (e.g., an aircraft on final approach) so that the capability to provide wind shear warnings to specific aircraft is included as part of the FIS capability.

3.1.3.2.1 Internal Interfaces

Internal interfaces include:
- Pilot/Display - On/Off Control

- Controller/Display - Input controls for message generation
- Ground/Aircraft - compatible transmitters, receivers and message formats
- Processor/Display - compatible message format and display driver

3.1.3.2.2 External Interfaces

External interfaces include FIS interfaces with:
- NAS-WIS - two way interface for data collection and status reporting
- ITWIS - one way interface for data collection
- Local Hazardous Weather Warning Systems- one way interface for data collection
- Local ATC facilities- two- way interface for data collection, status reporting, and controller inputs
- Data Link Message Delivery System- one way interface for data collection

3.1.3.3 Human Factors Considerations

The human factors considerations for FIS primarily revolve around the design of the FIS cockpit display and the graphical depiction of weather, including hazardous weather alerts and aeronautical information. This may be complicated by the need to use a multifunction cockpit display that will accommodate the display requirements of many of the other free flight operational enhancements. In addition, pilot interface with the display must include appropriate controls such as zoom, brightness, and contrast, alert off control, display on/off controls, and display mode controls.

If using a multifunction cockpit display, care must be taken to include features such that if an alert comes from a mode not presently being displayed, it will still be made known to the pilot. The human factor design of this multifunction cockpit display must consider the low-end general aviation user. In addition, interface of FIS products with the controller display is also part of FIS. Assume human factors, similar to the multifunction cockpit display, must be considered in this design of the FIS controller display.

3.1.3.4 FIS Requirements Traceability Matrices

Three aspects of requirement traceability are provided in this section. The first provides traceability between the FIS capabilities and the operational requirements as stated in the ATS 2005 CONOPS Narrative and the Joint Government/Industry Operational Concept. The second provides the functional allocation of the operational requirements derived from the ATS 2005 Narrative to the major ATC functions (i.e., communications, navigation, surveillance, weather, automation, maintenance and operations). The third aspect provides recommended requirements validation methodology for each of the functional requirements identified in Section 3.1.2.

3.1.3.4.1 Capabilities to CONOPS Traceability

These operational requirements are derived from the ATS 2005 CONOPS Narrative. They have been developed based upon key word searches of the ATS 2005 Operational Needs database. The key words used in these searches were based on the FIS capability descriptions obtained from the RTCA roadmap. Each FIS operational requirement is related to at least one FIS capability. Table 3.1.3.4.1 provides traceability between the FIS capabilities and the operational requirements. In addition, the cross reference of Government/Industry Operational Concept for the Evolution of Free Flight provided as Appendix B of the Joint Government/Industry Roadmap for Free Flight Operational Enhancements was used to provide traceability between the FIS capabilities and the RTCA requirements. This mapping is also provided as a column in Table 3.1.3.4.1.

3.1.3.4.2 Operational to Functional Requirement Traceability

Table 3.1.3.4.2 provides the functional allocation of the set of FIS operational requirements derived from the ATS 2005 CONOPS Narrative. It must be noted that the requirements obtained in this manner are not all directly related to the FIS since they apply to the broader NAS. They are included however for completeness since they result from the searches associated with each FIS capability and are part of the basis for the derived functional requirements presented in Section 3.1.2.

3.1.3.4.3 Procedures for Functional Requirement Verification

Table 3.1.3.4.3 provides the list of FIS functional requirements presented in Section 3.1.2 and the minimum test procedures to verify compliance with those functional requirements. These test procedures include the following test methods: inspection; analysis/simulation; laboratory tests; demonstrations; and, field/flight tests. For certain requirements more than one method may be indicated. Definitions for each of these verification methods are included below.

Table 3.1.3.4-1 FIS Capabilities and Requirements

	OPERATIONAL ENHANCEMENT Operational Capabilities	Key Words	Level 1 Narrative Operational Requirement	Joint Industry/Government CONOPS Capabilities Appendix B
1	**FIS for SUA Status, Weather, Wind Shear, NOTAMs, PIREPs**			**B1**
1.1	Pilots receive in-flight updates on status of SUAs of interest.	Information System,	1.23, 1.24, 2.2, 3.15 2.15, 4.34, 5.43, 5.46	5.2
		SUA		5.2
1.2	FIS to the cockpit including SUA status.	Data link,	3.5, 4.14, 5.24, 5.26	5.2
		Information	1.12, 1.23, 1.24, 2.2, 2.7, 2.12, 2.21, 3.15, 3.25, 3.26, 4.5, 4.7, 4.34, 4.53, 5.8, 5.23, 5.55, 6.39, 7.28	5.2
1.3	Pilots are able to receive in the cockpit current and forecast weather for airports (e.g., ATIS, RVR, wind shear/micro-burst alerts, braking action) of interest and along the route of flight via data link.	Data link,	3.5, 4.14, 5.24, 5.26	3.1, 3.2, 3.3, 4.1, 4.1.3, 4.2, 4.2.1, 4.3.3
		Information System	1.23, 1.24, 2.2, 3.15	3.1.1, 4.2, 4.3.3
1.4	Flight Information Service broadcasts integrated terminal area weather products with automatic updates for airborne aircraft.	Information System,	1.23, 1.24, 2.2, 3.15	3.1, 3.1.1, 3.3
		ATIS,	3.18, 3.25	3.1.1
		Broadcast	4.6, 7.78	
1.5	Up link of real time wind shear information to the aircraft.	Wind shear	4.6	3.1, 3.1.1, 3.2, 3.3, 4.1
1.6	Use a Flight Information Service (FIS) processor to collect and disseminate textual and graphic hazardous weather information to pilots, including WARP weather products.	Information System,	1.23, 1.24, 2.2, 3.15	3.1, 3.2, 3.3, 4.2, 4.2.1, 4.3.3, 5.2
		Hazardous Weather,	3.6, 4.6, 4.35	3.3, 4.2,
		Displays,	4.36	4.3.3, , 5.1, 5.1.2
		WARP	No Hits	
1.7	FIS to the cockpit including graphical weather, NOTAMs, PIREPs.	Displays, Information	4.36, 4.18 1.23, 1.24, 2.2, 3.15	3.3, 5.1, 5.1.2 3.1, 3.2, 3.2.2, 4.2, 4.2.1,
		System,		4.3.3, 5.2
		PIREP, NOTAM	No Hits	5.2

Table 3.1.3.4-2 FIS Functional Allocation of Operational Requirements

Level I #	ATS 2005 CONOPS Narrative Statement (Level I Need)	C	N	S	W	A	M
1.12	System processes and workstations are designed to expedite the exchange of information between NAS information systems, service providers, and users.!!Key Words: information (within 10 words of) exchange!!	C		S	W	A	
1.23	Information Distribution. A NAS-wide information system distributes timely and consistent information across the NAS, for both user and service provider planning. !!Key Words: NAS wide information system!!	C		S	W	A	M
1.24	This information system serves as an avenue for a greater exchange of electronic data and information between users and service providers. The system contains the following information:	C		S	W	A	M
2.2	Elements of the NAS-wide information system are used to obtain and distribute flight-specific data and aeronautical information, including international coordination of flight trajectory content. !!Keywords!!NAS-WIS!!	C				A	M
2.7	The year 2005 sees significant changes in the planning data available to users, and in the flight plan itself. … In 2005, planners and service providers have automated access to this information from the continuously and automatically updated NAS-wide information system. The scope of information is expanded to include items such as:!!Key Words: NAS-WIS	C		S	W	A	M
2.12	As conditions change during the planning phase, or during the flight, the planner continues to access the NAS-wide information system to determine the impact of the changes on the flight. !!Key Words: (in the same paragraph) NAS-WIS flight	C				A	
2.15	As the planner interactively generates the flight profile, information regarding current and predicted weather conditions, traffic density, restrictions and status of SUAs is available.!!Key Words: flight Profile!!	C		S	W	A	
3.5	communications are increasingly automated through the growing availability of datalink, while coordination and planning are aided by new decision support systems. Together, these systems enhance airport safety, improve efficiency and accommodate user preferences.!!Key Words: (or) datalink decision support systems	C				A	
3.6	Airport safety and efficiency is enhanced by terminal weather radar, automated weather observation systems, integrated systems to detect and predict hazardous weather, and improved surface detection equipment.!!Key Words: weather			S	W	A	

Level I #	ATS 2005 CONOPS Narrative Statement (Level I Need)	C	N	S	W	A	M
3.15	Aeronautical information … continue to be acquired by service providers and disseminated to users to aid in their planning and conduct of flight operations … this acquisition and dissemination is expedited by the NAS-wide information system.!!Key Words: aeronautical Information!!	C			W	A	M
3.18	Through the use of voice synthesis technology, ATIS messages are no longer manually recorded by service providers. Datalink allows most of these messages to be transmitted digitally.!!Key Words: ATIS	C				A	
3.25	The system provides access to airport environmental information, arrival, departure, and taxi schedules, airborne and surface surveillance information, flight information, ATIS and other weather information, and traffic management initiatives.	C		S	W	A	M
3.26	These data are shared with the NAS-wide information system.	C					M
4.5	Automatic exchange of information between flight deck and ground-based decision support systems improves the accuracy and coordination of arrival trajectories.	C	N	S	W	A	
4.6	Increasingly accurate weather displays are available to service providers. In addition, automatic broadcast of hazardous weather alerts for wind shear, micro-bursts, gust fronts, etc., are delivered simultaneously to the flight deck and service provider.	C			W	A	
4.7	Shared access to the NAS-wide information system allows an automated exchange of gate and runway preference data between the flight deck, the airline operations center, and the flight object.	C				A	
4.14	Pre-defined data link messages, such as altitude clearances and frequency changes, are uplinked to an increasing number of equipped aircraft.	C				A	
4.18	disruption in departure and arrival traffic is minimized by improved weather data and displays. Available to service providers and users, these data and displays enhance safety and efficiency by disclosing weather severity and location.!!Key Words: weather	C			W	A	
4.34	For airspace separation, accurate information on SUA status and planned usage is disseminated automatically to the service provider through the NAS-wide information system. !!Key words: (or) SUA status airspace separation	C				A	
4.35	The service provider has improved tools to assist pilots in avoiding hazardous weather.!!Key words: hazardous weather (or) HIWAS (in the same paragraph as) avoid	C		S	W	A	
4.36	Enhanced weather data and weather alerts are output on service provider displays, and simultaneously uplinked for display on the flight deck. !!Key Words: weather (in the same paragraph as) flight deck	C	N	S	W	A	

Level I #	ATS 2005 CONOPS Narrative Statement (Level I Need)	C	N	S	W	A	M
4.53	Through the NAS-wide information system, service providers also remain informed on distant weather conditions in order to anticipate changes to the daily traffic flow, and requests from other facilities.	C			W	A	M
5.8	The NAS-wide information system is continually updated with changes in airspace and route structures, and with the positions and predicted time-based trajectories of the traffic.	C		S		A	M
5.23	The temporary route structure that prevails at a given time is available to all service providers and users via the NAS-wide information system.	C				A	M
5.24	Complementary digital communication systems enable datalinking of routine communications	C				A	
5.26	The pilot in en route airspace has better downstream weather data information in digital form, both through automated means and through request/reply datalink.	C			W	A	
5.43	The activation of a SUA results in the reevaluation of all flight trajectories in the NAS-wide information system, to determine which flights will penetrate the SUA.!!Key Words: SUA	C		S		A	M
5.46	Decision support tools also help service providers to collaborate with users when SUA restrictions are later removed or changed.	C				A	
5.55	The service provider is given demand forecasts throughout the day via the continually updated NAS-wide information system.	C				A	M
6.39	The service provider has access to the NAS-wide information system as well as projected demand for the day.!!Key Words: demand	C		S		A	M
7.28	Users are better able to plan their flight … and to minimize congestion or possible delays due to the … NAS-wide information system.	C				A	M
7.78	Some infrastructure services such as navigation and landing signals, and aeronautical information broadcasts are provided directly to FAA customers.	C	N			A	M

Table 3.1.3.4-3 FIS Functional Requirements Verification Definitions

Insp	Inspection	Verification is based the determination that the system specification includes the requirement, the system was developed to include the capabilities of the requirement, and an examination of the system shows that the capabilities to meet the requirement were included. Results show that the required capability is in the system to the extent verifiable by inspection only.
A/S	Analysis / Simulation	Verification is based on analysis of the developed system capability. This analysis includes desk checking of characteristics and simulation. Operation of the system is not required. Results show that the specified capability, to the extent possible using analysis and simulation, was developed in the system in such a way the required capability is achievable.
Lab	Laboratory Test	Verification is based on operation of the system (in part or as a whole) in a laboratory environment. Some laboratory equipment may be used in place of operational equipment. Results show that specific required capabilities are achievable using the developed system (in part or as a whole) with laboratory instruments used for measurement and stimulation.
Demo	Demonstration Test	Verification is based on operation of the system (in part or as a whole) using operational equipment. Laboratory equipment is not used. Results show that the selected capability is observed using system components.
Field	Field Test	Verification is based on operation of the system using operational equipment in an operational environment. Results show that the selected capability is repeatedly demonstrable in an operational environment
Validation	Validation Test	Verification is based on operation of the system using operational equipment in an operational environment. Results of the comprehensive evaluation of thorough performance testing show that the full scope of the capability is achieved and is repeatable.

Table 3.1.3.4-4 FIS Functional Requirement Verification Procedures

Number	Functional Requirement	Insp	A/S	Lab	Demo	Field
1C-1	The FIS shall communicate with the NAS-WIS to obtain the information necessary to provide both broadcast and discrete FIS messages. When necessary, the NAS-WIS information shall be supplemented by communications with local facilities including ITWS, local ATC Facilities, and local weather and aeronautical information systems.		X	X	X	X
1C-2	The information to be obtained from external sources via appropriate communications media shall be timely and consistent across the NAS and shall include: flight specific data; aeronautical information; ATIS and other weather information; hazardous weather alerts for wind shear, gust fronts, and micro-bursts; SUA status; airspace configuration and route structure; and, current and forecast weather.		X		X	
1C-3	Communications between the FIS ground element and the aircraft shall be accomplished by broadcasting the FIS broadcast messages to aircraft in the FIS service area. Through the use of voice synthesis technology, ATIS messages are no longer manually recorded by service providers and these messages shall be transmitted digitally.				X	X
1C-4	Discrete communications between the FIS ground element and the aircraft shall be accomplished using a discrete addressing data link for delivery of FIS messages to specific aircraft. Complementary digital communications systems enable datalinking of routine communications and FIS discrete messages. PIREPS shall be provided directly to the NAS-WIS rather than to the FIS.				X	X
1C-5	Communications between the FIS ground element and the service provider shall be accomplished using appropriate Ground/Ground communications links including landlines, microwave, NADIN and the like.			X	X	
1N-1	The FIS system shall receive its navigational position from GPS, when available.				X	X
1N-2	The navigational position information shall be able to accommodate WAAS and LAAS satellite information, when available.			X		
1N-3	If GPS is not available, the aircraft shall use an appropriate area navigation instrument to provide an input to the FIS processor.			X	X	
1A-1	The FIS shall have automatic access to the NAS-WIS and all other essential sources of data in order to obtain timely and consistent data. The automatic data collection function shall , at a minimum, include collection of: flight specific data; aeronautical information; ATIS and other weather information, hazardous weather alerts for wind shear, gust fronts, and micro-bursts; SUA status; airspace configuration and route structure; and, current and forecast weather.		X	X	X	

1A-2	The FIS shall automatically collect and process all aircraft, weather and aeronautical information necessary to generate FIS broadcast and discrete messages.		**X**	**X**		
1A-3	The FIS shall automatically format all FIS broadcast and discrete message types.		**X**	**X**		
1A-4	The FIS shall automatically initiate the broadcast of all FIS broadcast messages according to a prescribed schedule and on an exception basis for emergency messages such as hazardous weather warnings.			**X**	**X**	
1A-5	The FIS ground element shall automatically provide a feed to the Controller Display generator and shall accept inputs from the controller via the controller display.			**X**	**X**	
1A-6	The FIS shall automatically correlate aircraft position with the location of hazardous weather, wind shear, gust fronts, and microburst activity. Specific hazardous weather messages shall be generated and formatted for specific aircraft based on this correlation. The FIS shall interface with an appropriate data link message processor to accomplish delivery of these discrete messages to a specific aircraft.		**X**	**X**	**X**	
1A-7	The FIS message processor on-board an aircraft may be integrated with other data link processing equipment including the flight management computer or the ATN equipment. This airborne FIS processor shall automatically process and format the FIS messages for display to the pilot.				**X**	**X**
1A-8	The FIS shall not respond to inputs from the pilot via the pilot's graphical display or through the flight management computer, or any other device interfaced with the FIS message processor other than to initiate or to terminate the display of FIS messages.	**X**		**X**		
1A-9	PIREPS shall be automatically generated on-board an aircraft external to the FIS equipment and shall be forwarded to the NAS-WIS and other appropriate facilities. The on-board, automatic PIREP system shall not directly interact with the FIS system.	**X**			**X**	**X**
1A-10	The FIS shall automatically provide messages to the service provider in such a format as to make optimal use of the service provider's advanced display capabilities.			**X**	**X**	
1A-11	The FIS shall provide an automatic method for verification and validation of the FIS messages.		**X**			
1OM-1	The FIS shall automatically monitor the status of the NAS-WIS and other external systems with which it is interfaced. It shall automatically reject information from an external system that is not operational.		**X**			

3.2 Controlled Flight Into Terrain (CFIT) Functional Specification

The functional specification for CFIT consists of a detailed description of the CFIT concept, a presentation of the CFIT functional requirements for each of the major ATC functions (i.e., Communications, Navigation, Surveillance, Weather, Automation and Maintenance and Operations) and an elaboration of the CFIT functional design including flow diagrams and interface requirements.

3.2.1 CFIT System Concept

The CFIT concept consists of a definition of the operational concept, the capabilities and the expected benefits. Within the operational concept, the CFIT mission and modes of operation are also defined. Figure 3.2.1-1 illustrates the CFIT concept. The CFIT system is totally contained on-board the aircraft and is dependent on a digitized three-dimensional database of the terrain and other obstructions. Maintenance of the database is a critical CFIT element, which is needed to guarantee that pilots are operating with current information. The CFIT functions consist primarily of data processing and navigation functions. The terrain and obstacle information displayed to the pilot will enhance the situational awareness in the cockpit as well as providing aural alerts indicating potential hazardous conditions.

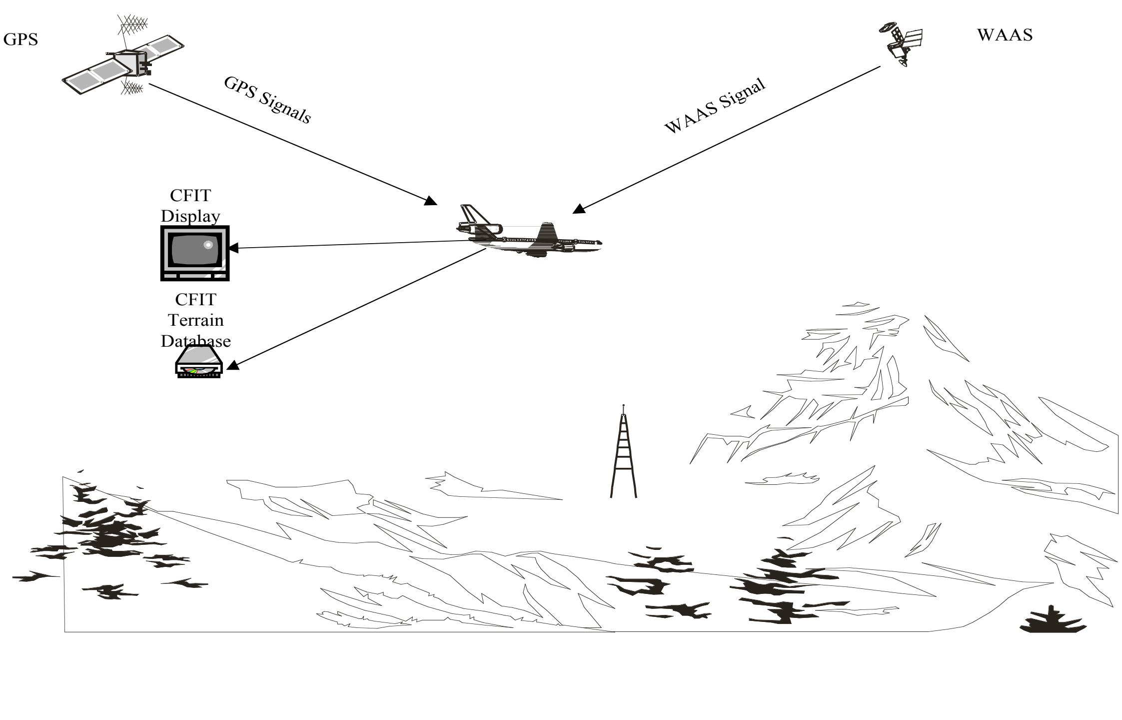


Figure 3.2.1-1 CFIT System Concept

3.2.1.1 CFIT Operational Concept

CFIT provides a detailed moving map of terrain and obstacles around an aircraft to help pilots maintain proper altitude and terrain clearance. Using the Global Positioning System (GPS), the aircraft's position is correlated with a database-driven terrain/obstacle map that provides the pilot with real time awareness of the aircraft's position relative to the terrain and obstacles. Loran, VOR and for DME may be used as a navigation backup to GPS but represent a degraded mode of operation. With this increased situational awareness, the number of CFIT accidents can be reduced. Cost effective CFIT will increase the use of such systems, reduce the CFIT rate and will allow increased low altitude airspace access for CFIT equipped aircraft.

3.2.1.1.1 Mission

In the United States from 1983 to 1994, CFIT incidents accounted for 32% of the GA accidents in instrument weather conditions. By making the pilot aware of the aircraft's proximity to surrounding terrain and obstacles, the number of CFIT accidents would be significantly reduced. Thus the mission of the CFIT system can be stated as:

Improve flight safety and airspace access through increased terrain/obstacle situational awareness

3.2.1.1.2 Modes of Operation

CFIT has two basic modes of operation:

- Situational awareness mode: In the situational awareness mode, the position of the aircraft relative to surrounding terrain and obstacles is displayed to the pilot on a moving map display.
- Alert/Warning Mode: In the alert/warning mode, both an aural alert is sounded and also a visual alert is displayed to warn the pilot that the aircraft is moving dangerously close to terrain or an obstacle.

3.2.1.2 CFIT Capabilities

The implementation of cost effective CFIT provides the following operational capabilities:

- Increase knowledge of ground proximity and reduce controlled flight into terrain with use of moving map displays integrated with a terrain/obstacle data base
- Use of terrain/obstacle data for CFIT avoidance
- Provide terrain data to support various levels of display capability
- Enhance pilot's situational awareness of terrain and obstacles with use of onboard three dimensional terrain information and aircraft's GPS position

3.2.1.3 CFIT Benefits

The CFIT system is expected to produce the following benefits:

- Increase in use of CFIT avoidance systems

- Reduce CFIT Rate
- Improve access to low altitude airspace for CFIT equipped aircraft

3.2.2 CFIT Functional Requirements

The functional requirements for CFIT have been developed by first considering the CFIT capabilities and then determining the relevant operational needs as stated in the ATS 2005 CONOPS Narrative. The operational needs were then analyzed to determine the ATC functions, which were required to satisfy the need. These CFIT operational requirements are presented as requirements traceability matrices in Section 3.2.3.3 and are summarized for each of the major ATC functions in the following paragraphs.

3.2.2.1 Communications

CFIT does not have any direct functional requirements in the communications area. It is, however, the requirement of the service provider to provide separation between the aircraft and terrain obstacles. The minimum safe altitude-warning decision support tool in the ground based automation system assists the service provider in keeping aircraft safely above terrain and avoiding obstacles.

3.2.2.2 Navigation

The CFIT requires precise navigational information that uses satellite information to derive position. An analysis of the detailed navigational requirements contained in the requirement traceability matrix results in the following set of navigational functional requirements:

1. The CFIT system shall receive its navigational position from GPS, when available.
2. The navigational position information shall be able to receive WAAS and LAAS satellite information, when available.
3. If GPS is not available, the aircraft shall use an appropriate area navigation instrument to provide an input to the CFIT processor.

3.2.2.3 Surveillance

The CFIT system does not have any direct functional requirements in the surveillance area. The separation of the aircraft from terrain/ obstacles remains the responsibility of the service provider. Surveillance is required for the service provider to provide terrain and obstacle separation services but not for the on-board CFIT system.

3.2.2.4 Weather

The CFIT system does not have any direct functional requirements in the weather area.

3.2.2.5 Automation

The CFIT system is dependent upon automation. The CFIT system collects and processes navigational information and terrain/obstacle information from the CFIT database. It then converts terrain contours and obstacle to the aircraft's coordinate system. This information is then formatted for display in the aircraft's cockpit. In addition, the CFIT system projects the aircraft position to determine if the aircraft will fly too close to the terrain or an obstacle. If the system determines that this will occur, it then generates an aural and a visual alert to warn the pilot of the impending danger. The CFIT system requires maintenance of its database to ensure the data integrity/currency of the digitized terrain database. CFIT has the following automation requirements:

1. The aircraft shall automatically collect navigational information. The navigational information shall be based on satellite data to the extent possible. The satellite navigational informational shall include WAAS and LAAS information. Other 3-D navigation data sources are acceptable in the event that satellite navigation data is not available. However use of alternative navigation represents a degraded mode of operation
2. The CFIT system shall interface with the aircraft's navigation system to obtain the estimate of aircraft position.
3. The CFIT system shall process the navigational information and terrain database and convert the information to the display coordinate system being used by the pilot.
4. CFIT shall correlate the aircraft position with proximate terrain contours and with obstacle positions and shall project the aircraft position to determine potential hazards.
5. The CFIT system shall format the position and terrain data to provide a graphical depiction on the CFIT display.
6. The CFIT system shall also provide aural and visual alerts to the pilot when a potential incident with terrain or an obstacle is detected.
7. The CFIT system shall not respond to inputs from the pilot via the pilot's graphical display or through the Flight Management Computer or the CFIT processor other than to initiate or terminate the graphical display, to set the scale for the display, or to terminate the aural alert indicator once it has been activated.
8. When GPS is not available and other navigation sources are used, CFIT shall display this degraded mode of operation to the pilot.

3.2.2.6 Operations and Maintenance

1. The CFIT system shall monitor the inputs received from the navigational source as well as the CFIT database to determine the integrity of the data as well as the operational status.
2. The CFIT system shall monitor its own operational status and report any malfunctions to the Flight Management computer and report its status.
3. The CFIT database shall be maintained with current information on obstacles and changes to terrain.

3.2.3 CFIT Functional Design

This section presents the functional design for the CFIT system that will satisfy the requirements and provide the capabilities previously described. Figure 3.2.1-2 represents the data flow for the CFIT system.

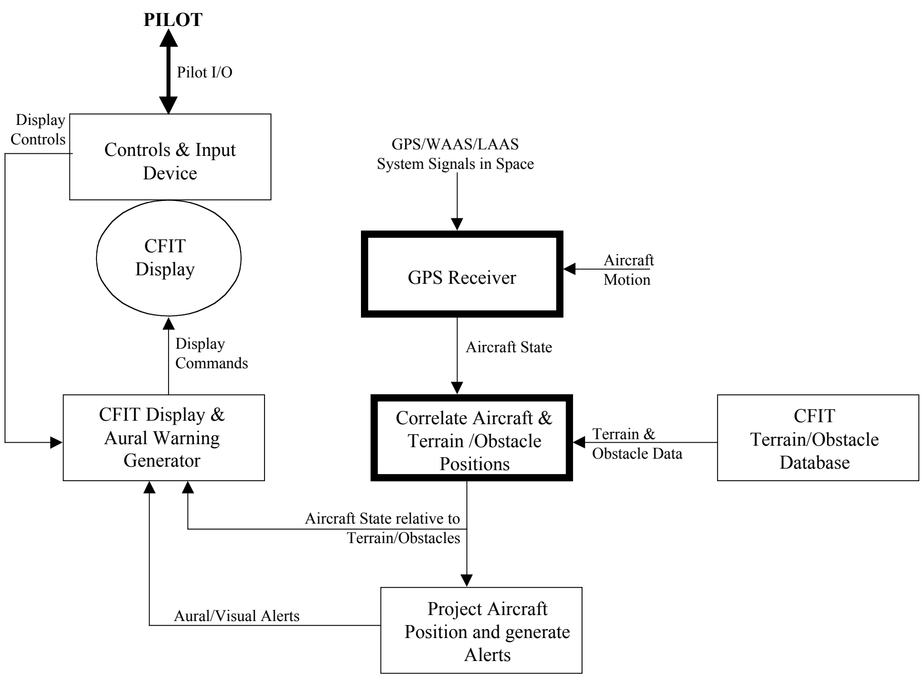


Figure 3.2.1-2 CFIT Functional Design

3.2.3.1 System Functional Relationships

CFIT provides a three dimensional view of the surrounding environment on a cockpit display for the pilot. The CFIT system is comprised of the three major components: the CFIT processor, the digitized terrain database and the graphical display/aural alert indicator. The CFIT processor receives the aircraft state from the GPS/Area Navigation receiver and the terrain contours and obstacle locations from the digitized terrain/obstacle database. It then converts the aircraft state position and the digitized terrain information to a common display coordinate system. Usually this coordinate system is own aircraft centered however the pilot may select an off centered system if this is desired. The converted information is formatted and passed on to the pilot graphical display via the moving map generator. The pilot interfaces with the graphical display via control switches associated with the graphical display.

The CFIT processor provides visual and aural alerts to the pilot if there is a potential threat of collision with the terrain or an obstacle. The CFIT processor compares the projected position of the aircraft with the digitized terrain/obstacle database. If the CFIT system detects an impending threat, an indication on the graphical display is depicted as well as sounding of an aural alert. At least 60 seconds of warning is provided to the pilot. The threatening terrain or obstacle are highlighted first with an amber indication and then with a red blinking indication at 30 seconds. The aural alert is sounded at 30 seconds.

3.2.3.2 Interface Requirements

CFIT is an avionics system designed to enhance the situational awareness of the pilot with respect to the surrounding terrain. CFIT interfaces with the GPS/WAAS satellite navigation receiver to determine its navigational position. The determination of the aircraft state from the navigational receiver is provided as an input to the CFIT processor. The CFIT processor interfaces internally with the GPS/Area Navigation receiver and the CFIT terrain database. The CFIT processor develops a three-dimensional picture of the surrounding environment for the pilot to improve situational awareness.

3.2.3.2.1 Internal Interfaces

Internal interfaces include:

- Pilot to Display- On/Off Control, Display Select Mode
- Pilot to Aural Alert –On/Off Control
- GPS Receiver to CFIT Processor -aircraft position and velocity
- CFIT Database to CFIT Processor - Terrain Contours and Obstacle Positions
- Processor to Display Generator - Relative positions and alert messages
- Display Generator to Display - Display commands to generate the appropriate CFIT display

3.2.3.2.2 External Interfaces

External interfaces include:

- GPS Satellite Constellation & GPS Receiver-one way interface to obtain estimate of aircraft state
- Other Navigation devices including Barometric Altimeter - one way interface to obtain estimate of aircraft state.

3.2.3.3 Human Factors Considerations

The human factors considerations for CFIT primarily revolve around the design of the CFIT moving map display, the three dimensional graphical depiction of the terrain information relative to own aircraft and the aural alert indicator. The moving map display may be complicated by the need to use a multifunction display that will accommodate the display requirements of many of the other free flight operational enhancements. In addition, pilot interface with the display must include appropriate controls such as zoom, brightness, and contrast, alert off control, display on/off controls, and display mode controls. If using a multifunction display, care must be taken to include features such that if an alert comes from a mode not presently being displayed, it will still be made known to the pilot. The human factor design of this multifunction display must consider the low-end general aviation user.

3.2.3.4 CFIT Requirements Traceability Matrices

Three aspects of requirement traceability are provided in this section. The first provides traceability between the CFIT capabilities and the operational requirements as stated in the ATS 2005 CONOPS Narrative and the Joint Government/Industry Operational Concept. The second provides the functional allocation of the operational requirements derived from the ATS 2005 Narrative to the major ATC functions (i.e., communications, surveillance, navigation, weather, automation, maintenance and operations). The third aspect provides recommended requirements validation methodology for each of the functional requirements identified in Section 3.2.2.

3.2.3.4.1 Capabilities to CONOPS Traceability

These operational requirements are derived from the ATS 2005 CONOPS Narrative. They have been developed based upon key word searches of the ATS 2005 Operational Needs database. The key words used in these searches were based on the CFIT capability descriptions obtained from the RTCA Roadmap. Each CFIT operational requirement is related to at least on CFIT capability. Table 3.2.3.4-1 provides traceability between the CFIT capabilities and the operational requirements. In addition, the cross-reference of Government/Industry Roadmap for Free Flight Operational Enhancements was used to provide traceability between the CFIT capabilities and the RTCA requirements. This mapping is also provided as a column in Table 3.2.3.4.1.

3.2.3.4.2 Operational to Functional Requirement Traceability

Table 3.2.3.4-2 provides the functional allocation of the set of CFIT operational requirements derived from the ATS 2005 CONOPS Narrative. It must be noted that the requirements obtained in this manner are not all directly related to the CFIT since they apply to the broader NAS. They are included, however, for completeness since they result from the searches associated with each CFIT capability are part of the basis for the derived functional requirements presented in Section 3.2.2.

3.2.3.4.3 Procedures for Functional Requirement Verification

Table 3.1.3.4.3 provides the list of CFIT functional requirements presented in Section 3.2.2 and the minimum test procedures to verify compliance with those functional requirements. These test procedures include the following test methods: inspection, analysis/simulation, laboratory tests, demonstrations, and field/flight tests. For certain requirements, more than one method may be indicated. Definitions for each of these verification methods are included below.

Table 3.2.3.4-1 CFIT Capabilities and Requirements

	OPERATIONAL ENHANCEMENT Operational Capabilities	Key Words	Level 1 Narrative Operational Requirement	Joint Industry/Government CONOPS Capabilities Appendix B
2	**Cost Effective CFIT Avoidance, Situational Awareness**			**B2**
2.1	Use of moving map displays with integrated terrain database to increase knowledge of ground proximity and reduce CFIT.	Displays,	1.9	5.1, 5.1.2
		Terrain	2.16, 4.31, 4.33, 5.6.1	4.1, 4.1.2
2.2	Use of terrain/obstacle data for CFIT avoidance.	Terrain,	2.16, 4.31, 4.33, 5.6.1	4.1
		Obstacle,	No Hits	
		Obstruction	4.21, 4.32, 4.33	4.1.2
2.3	Use onboard three dimensional terrain information and aircraft's GPS position to enhance pilot's awareness of terrain and obstacles.	Terrain,	2.16, 4.31, 4.33, 5.6.1	4.1, 4.1.2
		Obstacle,	No Hits	4.1.2
		Satellite,	1.9, 4.3, 4.11, 4.60, 5.20	5.1
		Obstruction	4.21, 4.32, 4.33	
2.4	Provide terrain data to support various levels of display capability.	Terrain,	2.16, 4.31, 4.33, 5.6.1	4.1, 4.1.2
		Displays	1.9	5.1, 5.1.2

Table 3.2.3.4-2 CFIT Functional Allocation of Operational Requirements

Level I #	ATS 2005 Statement (Level I Need)	C	N	S	W	A	M
1.9	Replacement of Host … transition to satellite navigation …new display platforms!!Key Words: host navigation display		N			A	
2.16	When the profile is filed, it is automatically checked against these conditions and any static constraints such as terrain and infrastructure advisories. !!Key Words: (in the same paragraph as) profile checked	C		S	W	A	M
4.3	Departure and arrival route structures are expanded … to allow increased usage of area navigation (RNAV), satellite navigation, and routes flown automatically by the onboard Flight Management System (FMS).!!Key Words: (or) routes NAV GPS satellite Navigation FMS!!	C	N			A	
4.11	Tools such as FMS, datalink, and satellite navigation allow the route flexibility by reducing voice communications and increasing navigational precision.	C	N			A	
4.21	Separation assurance has undergone changes in the following areas: aircraft-to-aircraft separation, aircraft-to-airspace and aircraft-to-terrain/obstruction separation, and departure and arrival planning services.!!Key Words: separation	C	N	S		A	
4.31	Aircraft-to-airspace and aircraft-to-terrain separation also remains the service provider's responsibility.	C		S		A	
4.32	The service provider maintains separation between controlled aircraft and active SUAs, and between controlled aircraft and terrain/obstructions.	C		S		A	
4.33	An automated safe-altitude warning function enables the service provider to keep aircraft safely above terrain and obstructions.!!Key Words: (or) altitude warning terrain	C		S		A	
4.60	The current ground-based navigation systems are in transition to satellite-based systems.!!Key Words: navigation		N			A	
5.6.1	Structured routes are the exception rather than the rule, and exist only when required to meet continuous high density, to provide for the avoidance of terrain and active SUAs, and to facilitate the transition between areas with differing separation standards.					A	M
5.20	As ground based navaids phase out with the transition to satellite navigation, the current route structure is replaced with a global grid of named locations. !!		N	S		A	

Table 3.2.3.4-3 Functional Requirements Verification Definitions

Insp	Inspection	Verification is based the determination that the system specification includes the requirement, the system was developed to include the capabilities of the requirement, and an examination of the system shows that the capabilities to meet the requirement were included. Results show that the required capability is in the system to the extent verifiable by inspection only.
A/S	Analysis / Simulation	Verification is based on analysis of the developed system capability. This analysis includes desk checking of characteristics and simulation. Operation of the system is not required. Results show that the specified capability, to the extent possible using analysis and simulation, was developed in the system in such a way the required capability is achievable.
Lab	Laboratory Test	Verification is based on operation of the system (in part or as a whole) in a laboratory environment. Some laboratory equipment may be used in place of operational equipment. Results show that specific required capabilities are achievable using the developed system (in part or as a whole) with laboratory instruments used for measurement and stimulation.
Demo	Demonstration Test	Verification is based on operation of the system (in part or as a whole) using operational equipment. Laboratory equipment is not used. Results show that the selected capability is observed using system components.
Field	Field Test	Verification is based on operation of the system using operational equipment in an operational environment. Results show that the selected capability is repeatedly demonstrable in an operational environment
Validation	Validation Test	Verification is based on operation of the system using operational equipment in an operational environment. Results of the comprehensive evaluation of thorough performance testing show that the full scope of the capability is achieved and is repeatable.

Table 3.2.3.4.4 CFIT Functional Requirement Verification Procedures

Number	Functional Requirement	Insp	A/S	Lab	Demo	Field
2N-1	The CFIT system shall receive its navigational position from GPS, when available.				X	X
2N-2	The navigational position information shall be able to receive WAAS and LAAS satellite information, when available.			X		
2N-3	If GPS is not available, the aircraft shall use an appropriate area navigation instrument to provide an input to the CFIT processor.			X	X	
2A-1	The aircraft shall automatically collect navigational information. The navigational information shall be based on satellite data to the extent possible. Other 3-D navigation data sources are acceptable in the event that satellite navigation data is not available. The satellite navigational informational shall include WAAS and LAAS information.			X	X	
2A-2	The CFIT system shall interface with the aircraft's navigation system to obtain the estimate of aircraft position.				X	X
2A-3	The CFIT system shall process the navigational information and terrain database and convert the information to the display coordinate system being used by the pilot.				X	X
2A-4	CFIT shall correlate the aircraft position with proximate terrain contours and with obstacle positions and shall project the aircraft position to determine potential hazards.			X	X	X
2A-5	The CFIT system shall format the position and terrain data to provide a graphical depiction on the CFIT display.			X	X	X
2A-6	The CFIT system shall also provide aural and visual alerts to the pilot when a potential incident with terrain or an obstacle is detected.			X	X	X
2A-7	The CFIT system shall not respond to inputs from the pilot via the pilot's graphical display or through the Flight Management Computer or the CFIT processor other than to initiate or terminate the graphical display, to set the scale of the display, or to terminate the aural alert indicator once it has been activated.			X	X	
2OM-1	The CFIT system shall monitor the inputs received from the navigational source as well as the CFIT database to determine the integrity of the data as well as the operational status.			X		
2OM-2	The CFIT system shall monitor its own operational status and report any malfunctions to the Flight Management computer and report its status.			X		
2OM-3	The CFIT database shall be maintained with current information on obstacles and changes to terrain.				X	

3.3 Low Visibility Terminal Operations (LVTO) Functional Specification

The functional specification for the LVTO consists of a detailed description of the system concept, a presentation of the functional requirements for each of the major ATC functions (i.e., Communications, Navigation, Surveillance, Weather, Automation, and Maintenance and Operations), and an elaboration of the design including functional flow diagrams and interface requirements.

3.3.1 LVTO System Concept

The LVTO concept consists of a definition of the operational concept, the capabilities, and the expected benefits. Within the operational concept, the LVTO mission and modes of operation are also defined. Figure 3.3.1-1 illustrates the LVTO concept and shows that it consists primarily of data collection and processing, and communication functions. The LVTO will improve the pilot's situational awareness in the terminal domain in low visibility conditions. The pilot's situational awareness will be improved by the CDTI in the cockpit, enabling the pilot to identify aircraft to follow. The LVTO also provides additional information to the cockpit via the data link processor for TIS information. The data link processor will also provide station-keeping commands to the pilot.

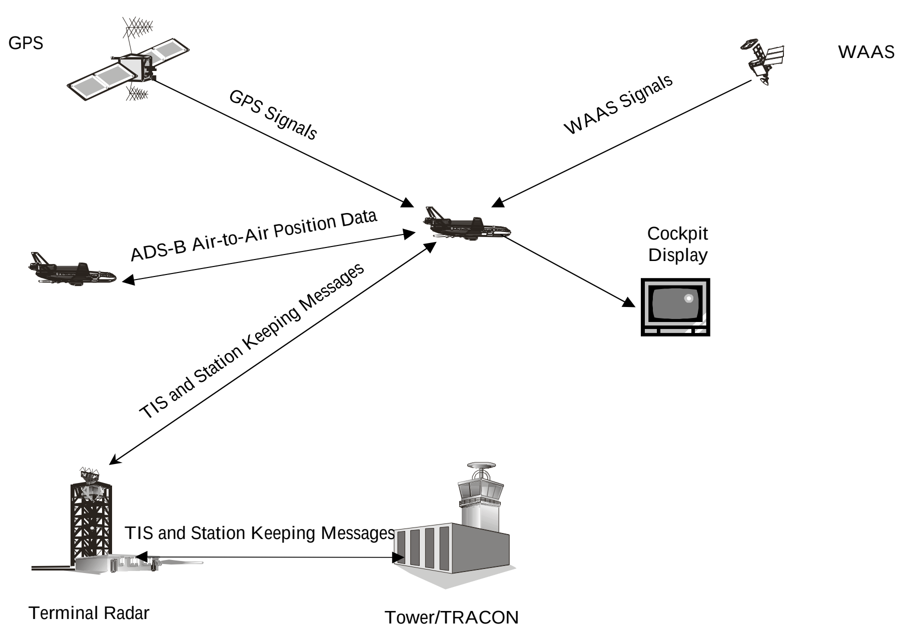


Figure 3.3-1 LVTO System Concept

3.3.1.1 LVTO Operational Concept

The LVTO concept provides the flight crew with traffic information in terminal areas with respect to nearby aircraft. The information is obtained in the aircraft from the TIS installation on the airport and/or from ADS-B. Other aircraft are presented to the pilot on a CDTI display.

The fundamental operational concept is for the pilot to use a CDTI which displays traffic data received by means of ADS-B and/or TIS during low visibility approach operations to better identify proximate aircraft and the aircraft to be followed during approach and to accomplish VFR approaches at lower visibility minimums. This will enable VFR throughput to be maintained for a larger fraction of time than is currently achievable; crews will also be able to maintain better spacing during VFR and IFR approaches.

3.3.1.1.1 Mission

The LVTO mission is to improve safety and efficiency during low visibility terminal operations. Enabling aircraft to maintain proper spacing will enhance safety, thereby avoiding possible violations of minimum separation requirements and reducing the occurrences of missed approaches. Efficiency is enhanced by enabling VFR throughput to be maintained under meteorological conditions that now require IFR approaches. Thus, the mission of the LVTO system can be stated as:

Improve flight safety, efficiency and operations in low visibility terminal approaches

3.3.1.1.2 Modes of Operation

ERA/A has two basic modes of operation:

- Situational awareness mode: In the situational awareness mode, the position of the aircraft relative to surrounding aircraft is displayed to the pilot on a moving map display.
- Broadcast Mode: In the broadcast mode, a common frequency, 1090 MHz, is used to broadcast ADS-B messages to all aircraft within reception range.

3.3.1.2 LVTO Capabilities

The implementation of LVTO provides the following operational capabilities:

- Improve visual approaches in lower visibility/ceiling conditions utilizing ADS-B/CDTI and TIS capabilities
- Improve the flow of traffic at separation minima lower than current IFR standard using ADS-B and CDTI based station keeping
- Support in-trail IFR departures over common noise abatement routes
- Reduce separation in the terminal environment
- Enhance visual acquisition of traffic
- Allow airports to maintain visual acceptance rates for longer periods of time
- Increase pilot situational awareness using ADS-B/CDTI and TIS capabilities.

3.3.1.3 LVTO Benefits

The LVTO is expected to produce the following benefits:

- Increase access to airports
- Increase arrival rates
- Reduce arrival delays
- Increase predictability of arrival times
- Increase flexibility of arrival scheduling
- Increase airport capacity

3.3.2 LVTO Functional Requirements

The functional requirements for LVTO have been developed by first considering the LVTO capabilities and then determining the relevant operational needs as stated in the ATS 2005 CONOPS Narrative. The operational capabilities and needs were then analyzed to determine the ATC functions, which were required to satisfy the need. These LVTO operational requirements are presented as requirements traceability matrices in Section 3.3.3.4 and are summarized for each of the major ATC functions in the following paragraphs.

3.3.2.1 Communications

The communications requirements for LVTO are primarily associated with transmitting and receiving ADS-B aircraft state information and with receiving TIS messages over a data link. The TIS messages consist of aircraft state information, other TIS messages and station keeping clearances. An analysis of the detailed communications requirements contained in the requirement traceability matrix coupled with an examination of the required capabilities results in the following set of communications functional requirements:

1. The LVTO shall receive own aircraft position and velocity from GPS which may be augmented with LAAS and/or WAAS and shall broadcast ACID, Position, and velocity in the standardized ADS-B formats
2. The LVTO shall receive the ADS-B states of other aircraft
3. The LVTO shall receive TIS data link messages via the appropriate data link and shall distribute these messages to the display generator and to the on-board TIS/ADS-B Correlator and Coordinate Conversion processor.
4. The LVTO shall receive station-keeping clearances from the controller via data link and shall distribute these messages to the LVTO station keeping aid.
5. Voice communications shall be available between the pilot and the controller however this is not considered an LVTO functional requirement
6. The LVTO shall communicate operation in a degraded navigational mode to the ground based ATC system when this situation occurs.

3.3.2.2 Navigation

The LVTO requires precise navigational information that uses satellite or augmented satellite information to derive position. An analysis of the detailed navigational requirements contained in the requirement traceability matrix results in the following set of navigational functional requirements:

1. The LVTO system shall receive its navigational position from GPS, when available.
2. The navigational position information shall be able to receive WAAS and LAAS satellite information, when available.
3. If GPS is not available, the aircraft shall use an appropriate area navigation instrument to provide an input to the LVTO processor.

3.3.2.3 Surveillance

LVTO has no direct ATC surveillance requirements although it is assumed that the aircraft is under ATC surveillance and control especially during low visibility terminal operations. LVTO does however depend upon air-to-air surveillance, which is supplemented with TIS aircraft states from the ground. This is necessary in order to assure that non-ADS-B equipped aircraft will also be under the surveillance of the pilot using the CDTI. An analysis of the detailed surveillance requirements contained in the requirement traceability matrix (Section 3.3.3.4) coupled with an examination of the required LVTO capabilities results in the following set of airborne surveillance functional requirements:

1. LVTO shall receive ADS-B and TIS aircraft states from the ADS-B air-to-air broadcasts of aircraft state and from the TIS discrete data link messages.
2. LVTO shall correlate the received TIS aircraft states and the ADS-B aircraft states in order to eliminate duplicate target reports on the same aircraft
3. LVTO shall broadcast its own aircraft state for use by the ground ATC surveillance system and for air-to-air surveillance by other properly equipped aircraft.

3.3.2.4 Weather

LVTO does not have any directly related functional requirements in the weather area. However, LVTO is intended to improve terminal operations during low visibility weather conditions by providing the pilot with increased awareness of surrounding traffic.

3.3.2.5 Automation

The automation functions required by LVTO involve the processing of ADS-B and TIS aircraft state information, the development of appropriate commands to drive the CDTI display and, an optional function to assist the pilot in station keeping. ATC automation is not considered part of the LVTO system but it is recognized that it must provide inputs to the LVTO using the TIS. Analysis of the detailed automation requirements contained in the requirement traceability matrix (Section 3.3.3.4) coupled with an examination of the required LVTO capability results in the following set of airborne automation functional requirements:

1. LVTO shall automatically correlate the received TIS aircraft states and the ADS-B aircraft states in order to eliminate duplicate target reports on the same aircraft
2. LVTO shall automatically convert all aircraft states into own aircraft relative coordinates
3. LVTO shall automatically process all display inputs from the pilot. These inputs shall at a minimum include control of display brightness, contrast, location of own aircraft on the display, and on/off controls.

4. LVTO shall automatically process and display station keeping clearances and other ATC data link messages
5. LVTO may, as an option, incorporate an automated station keeping aid to assist the pilot in performing accurate station keeping maneuvers. This aid will be incorporated into the CDTI if it is made available.
6. LVTO shall automatically inform the ground based ATC system of operation in a degraded mode

3.3.2.6 Operations and Maintenance

1. The LVTO system shall monitor the inputs received from the navigational source as well as to determine the integrity/reasonableness of the aircraft state and data link messages received.
2. The LVTO system shall monitor its own operational status and shall automatically report any malfunctions to the ATC system.

3.3.3 LVTO Functional Design

This section presents the functional design for the ERA/A system that will satisfy the requirements and provide the capabilities previously described. Figure 3.3.3-1 represents the data flow for the ERA/A system.

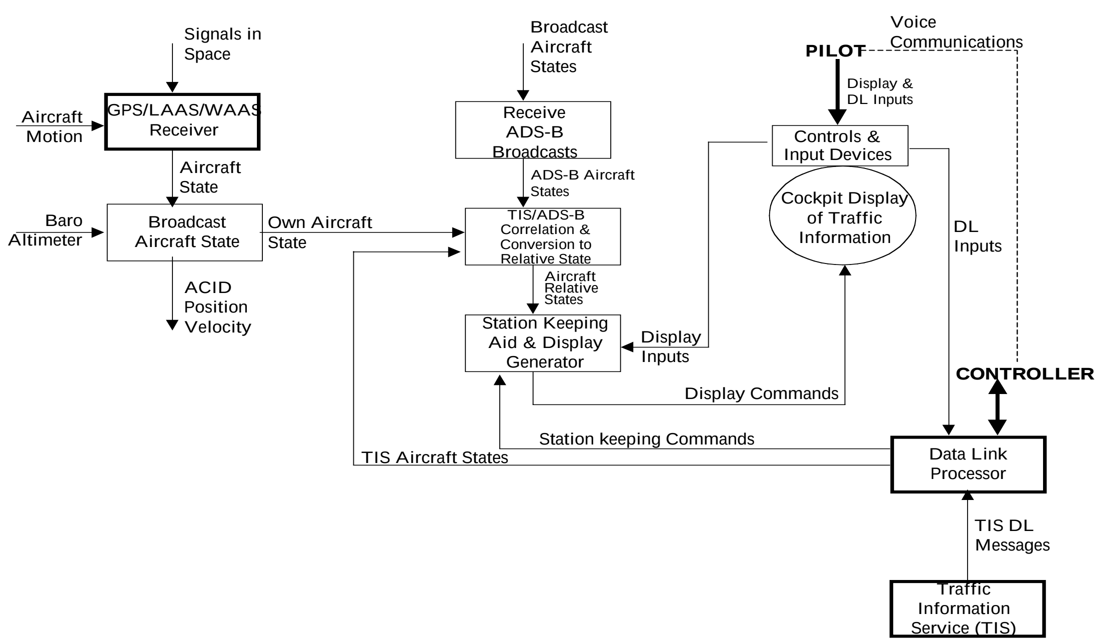


Figure 3.3.3-1 LVTO Functional Block Diagram

3.3.3.1 System Functional Relationships

The LVTO will enable pilots to improve their ability to identify aircraft in the terminal domain in low visibility conditions and to perform station keeping during approach. The LVTO system receives GPS signals to determine its own navigational position as well as other aircraft broadcasts, which includes information about the aircraft state. The LVTO correlates and converts the received TIS and ADS-B information to own aircraft coordinates. The TIS information is received from the data link processor located on the ground. The TIS and ADS-B information provide information for the Station Keeping Aid and Display Generator. The Station Keeping Aid and Display Generator provide the display commands to the CDTI. The pilot provides display and data link inputs to the CDTI via the Controls and Input device.

3.3.3.2 Interface Requirements

The LVTO interfaces with the GPS satellite constellation to determine its navigational position. The determination of the aircraft state from the satellite constellation and the reception of broadcast messages from other aircraft provide an input to the LVTO processor. The LVTO processor interfaces internally with the display generation to provide display commands to the pilot graphical display.

The LVTO also interfaces with the data link processor located on the ground. The data link processor interfaces with the TIS to provide TIS aircraft states and Station Keeping commands to the LVTO processor.

3.3.3.2.1 Internal Interfaces

Internal interfaces include:

- Pilot/Display - On/Off Control
- Processor/Display - compatible message format and display driver

3.3.3.2.2 External Interfaces

External interfaces include LVTO interfaces with:

- GPS Satellite Constellation & GPS Receiver-one way interface to obtain estimate of aircraft state
- Aircraft Transceiver and other aircraft transceivers-two way interface to send/receive aircraft position
- Data Link Message Delivery System- one way interface for data collection

3.3.3.3 Human Factors Considerations

The human factor considerations for LVTO primarily revolve around the design of the LVTO display and the graphical depiction of the location of traffic of interest. This may be complicated by the need to use a multifunction cockpit display that will accommodate the display requirements of many of the other free flight operational enhancements. In addition, pilot interface with the display must include appropriate controls such as zoom, brightness, and contrast, alert off control, display on/off controls, and display mode controls. If using a multifunction cockpit display, care must be taken to include features such that if an alert comes from a mode not presently being displayed, it will still be made known to the pilot. The human factor design of this multifunction cockpit display must consider the low-end IFR general aviation user.

3.3.3.4 LVTO Requirements Traceability Matrices

Three aspects of requirement traceability are provided in this section. The first provides traceability between the LVTO capabilities and the operational requirements as stated in the ATS 2005 CONOPS Narrative and the Joint Government/Industry Operational Concept. The second provides the functional allocation of the operational requirements derived from the ATS 2005 Narrative to the major ATC functions (i.e., communications, navigation, surveillance, weather, automation, maintenance and operations). The third aspect provides recommended requirements validation methodology for each of the functional requirements identified in Section 3.3.2.

3.3.3.4.1 Capabilities to CONOPS Traceability

These operational requirements are derived from the ATS 2005 CONOPS Narrative. They have been developed based upon key word searches of the ATS 2005 Operational Needs database. The key words used in these searches were based on the LVTO capability descriptions obtained from the RTCA roadmap. Each LVTO operational requirement is related to at least one LVTO capability. Table 3.6.3.4.1 provides traceability between the LVTO capabilities and the operational requirements. In addition, the cross reference of Government/Industry Operational Concept for the Evolution of Free Flight provided as Appendix B of the Joint Government/Industry Roadmap for Free Flight Operational Enhancements was used to provide traceability between the LVTO capabilities and the RTCA requirements. This mapping is also provided as a column in Table 3.6.3.4.1.

3.3.3.4.2 Operational to Functional Requirement Traceability

Table 3.3.3.4.2 provides the functional allocation of the set of LVTO operational requirements derived from the ATS 2005 CONOPS Narrative. It must be noted that the requirements obtained in this manner are not all directly related to the LVTO since they apply to the broader NAS. They are included however for completeness since they result from the searches associated with each LVTO capability are part of the basis for the derived functional requirements presented in Section 3.3.2.

3.3.3.4.3 Procedures for Functional Requirement Verification

Table 3.3.3.4.3 provides the list of LVTO functional requirements presented in Section 3.3.2 and the minimum test procedures to verify compliance with those functional requirements. These test procedures include the following test methods: inspection; analysis/simulation; laboratory tests; demonstrations; and, field/flight tests. For certain requirements more than one method may be indicated. Definitions for each of the verification methods are included below.

Table 3.3.3.4-1 LVTO Capabilities and Requirements

	OPERATIONAL ENHANCEMENT Operational Capabilities	Key Words	Level 1 Narrative Operational Requirement	Joint Industry/Government CONOPS Capabilities Appendix B
3	**Improved Terminal Operations in Low Visibility Conditions**			**B3**
3.1	Develop procedures to utilize ADS-B/CDTI capabilities to improve visual approaches in lower visibility/ceiling conditions. ...Given the inherent precision of LAAS and ADS-B, much smaller obstacle clearance (on the order of a few hundred feet) should be possible leading to increased availability of visual approaches to multiple runways.	Satellite,	1.9, 3.30, 4.12, 4.60, 4.62, 5.7, 5.41, 6.6, 6.14, 6.24	
		Display,	1.9, 4.12, 4.24, 6.23,	4.1
		Approach,	4.45, 4.62, 4.63, 4.64	4.1, 4.1.1
		Augmentation,	4.63	
		Obstacle,	No Hits	
		Obstruction	4.21, 4.32, 4.33	
3.2	Use ADS-B and CDTI based station-keeping to improve the flow of traffic at separation minima lower than the current IFR standard.	Station,	4.45, 6.26	4.1
		Display,	1.9, 4.12, 4.24, 6.23,	4.1
		Separation	1.17, 1.34, 4.12, 4.23, 4.63, 5.6.1, 5.18, 6.13, 6.21, 6.22	, 4.1.1, 4.3
3.3	Using ADS-B to support in-trail departures over common noise abatement routes.	Noise,	No Hits	
		Trail,	No Hits	
		Departures	3.38, 4.3, 4.39, 4.66, 4.68	
3.4	Reduced separation in the terminal environment.	Separation	4.63	4.1, 4.1.1, 4.2,4.2.1, 4.3
3.5	Use ADS-B and CDTI to enhance visual acquisition of traffic improving the safety of visual approaches and allowing airport to maintain visual acceptance rates for longer periods.	Visual,	4.23	4.1.1
		Display,	1.9, 4.12, 4.24, 6.23,	
		Satellite	3.30, 4.12, 4.39	
3.6	ADS-B/TIS CDTI to increase pilot situational awareness and increase airport capacity.	Awareness,	4.12, 6.23	4.1
		Satellite,	3.30, 4.12, 5.41	
		Capacity	1.19, 7.65	

Table 3.3.3.4-2 LVTO Functional Allocation of Operational Requirements

Level I #	ATS 2005 Statement (Level I Need)	C	N	S	W	A	M
1.9	Replacement of Host … transition to satellite navigation …new display platforms!!Key Words: host navigation display		N			A	
1.17	Air safety has been increased through the implementation of conflict detection and resolution tools, the inclusion of the flight deck in some separation decision-making, and greatly enhanced weather detection and reporting capabilities. !!Key Words: conflict detection resolution separation weather !!	C		S	W	A	
1.19	Phased Technology Implementation. The evolution of the operational environment is based on an incremental implementation of new technologies. This approach maintains safety as the first priority, while also increasing capacity, efficiency, and flexibility in a balance with environmental considerations. !!Key Words: safety capacity efficiency flexibility	C	N	S	W	A	M
1.34	These tools reduce the burden of routine tasks while increasing the provider's ability to evaluate traffic situations and plan the appropriate response. This increases productivity and provides greater flexibility to user operations, with potential reduced vertical separation minima and increased traffic density.					A	
3.30	Service providers can display satellite-derived position data transmitted by selected flights upon request, while ground-based surveillance data is shared with users as a safety enhancement for preventing incursions.	C		S		A	
3.38	For departures, the decision support system incorporates departure times, aircraft type, wake turbulence criteria, and departure routes to safely and efficiently sequence aircraft to the departure threshold.!!Key Words: departure (in the same paragraph as) DSS					A	
4.3	Departure and arrival route structures are expanded … to allow increased usage of area navigation (RNAV), satellite navigation, and routes flown automatically by the onboard Flight Management System (FMS).!!Key Words: (or) routes NAV GPS satellite Navigation FMS!!	C	N			A	
4.12	Satellite-based position data, broadcast by properly equipped aircraft, are used in cockpit traffic displays to increase the pilots' situation awareness for aircraft-to-aircraft separation. These avionics allow an increasingly frequent transfer of responsibility for separation assurance to the flight deck for some types of operations.!!Key Words: self separation!!	C	N	S		A	
4.21	Separation assurance has undergone changes in the following areas: aircraft-to-aircraft separation, aircraft-to-airspace and aircraft-to-terrain/obstruction separation, and departure and arrival planning services.!!Key Words: separation	C	N	S		A	

Level I #	ATS 2005 Statement (Level I Need)	C	N	S	W	A	M
4.23	Visual separation by pilots in terminal areas is expanded to allow all-weather pilot separation when deemed appropriate by the service provider.	C		S	W	A	
4.24	The increased use of this shared responsibility is made feasible through traffic displays on the flight deck, and rules, procedures, and training programs that have modified the roles and responsibilities of users and service providers.					A	M
4.32	The service provider maintains separation between controlled aircraft and active SUAs, and between controlled aircraft and terrain/obstructions.	C		S		A	
4.33	An automated safe-altitude warning function enables the service provider to keep aircraft safely above terrain and obstructions.!!Key Words: (or) altitude warning terrain	C		S		A	
4.39	Improved departure flows are achieved through tools that provide more efficient airport surface operations, improved real time assessment of traffic activity in departure and en route airspace, and expanded usage of flexible routes based on RNAV, satellite navigation, and FMS.!!Key Words: departure flow	C	N	S		A	
4.45	On final approach, the service provider may give the pilot responsibility for station keeping to maintain the required sequence and spacing to the runway.	C	N	S		A	
4.60	The current ground-based navigation systems are in transition to satellite-based systems.!!Key Words: navigation		N			A	
4.62	Approach guidance, currently provided by ground-based systems, is supplemented by satellite-based approaches !!Key Words: approach guidance		N			A	
4.63	Augmentation systems have the accuracy, availability, integrity, and continuity necessary for precision approaches. Separation standards are set in accordance to the accuracy of the positional information.!!Key Words: precision approach		N			A	M
4.64	This transition results in precision approaches being available at more airports, increasing all-weather access to an increasing number of airports.		N		W	A	
4.66	More flexible departure routes are possible … as more aircraft are equipped with advanced navigation systems, and the service provider has automated support to verify adherence to the selected profile. !!Key Words: flexible (within 10 words of) routes monitor (within 10 words of) aircraft surveillance (in the same paragraph as) automation	C	N	S		A	
4.68	Advance coordination of planned departure routes during the pre-flight phase make more flexible routing possible.	C				A	
5.6.1	Structured routes are the exception rather than the rule, and exist only when required to meet continuous high density, to provide for the avoidance of terrain and active SUAs, and to facilitate the transition between areas with differing separation standards.					A	M

Level I #	ATS 2005 Statement (Level I Need)	C	N	S	W	A	M
5.7	Surveillance of all positively controlled aircraft is provided by a combination of primary and secondary radar, and the broadcast of satellite-derived position information by individual flights.!!Key Words: surveillance	C		S		A	
5.18	Separation standards depend on the flight's equipage and the quality of the positional data, service provider displays indicate the quality of the resulting aircraft positions and the appropriate equipage information. !!Key Words: separation Standards	C		S		A	
5.41	For VFR aircraft automatically reporting their satellite-derived positions … coupled with access to the flight's data via the NAS-wide information system, reduces the workload associated with providing traffic advisories to uncontrolled aircraft.!!Key Words: traffic advisories	C	N	S		A	M
6.6	Satellite navigation systems and datalink allow more accurate and frequent traffic position updates; datalink and expanded radio coverage provide direct air-to-ground communications (both digital and voice).!!Key Words: navigation	C	N	S		A	
6.13	Most aircraft navigate using a global satellite navigation system whose improved accuracy generates the required safety for reduced separation standards.		N				
6.14	The combination of satellite-based communications and electronic message routing enables the oceanic system to be more interactive and dynamic, supporting cooperative activities among flight crews, AOCs, and service providers.!!Key Words: communications	C				A	
6.21	The oceanic service provider has a display of traffic in the oceanic airspace, ensuring separation in the same manner as in domestic airspace, although the separation criteria may be different.	C		S		A	
6.22	The oceanic environment creates opportunity for the transfer of separation assurance to the pilot for specific operations.	C		S		A	
6.23	Pilots have situation awareness of nearby traffic through a cockpit display of traffic information.!!Key Words: CDTI	C		S		A	
6.24	Aircraft position updates are supplied by the aircraft's broadcast of satellite navigation-derived position data transmissions.!!Key Words: position reports	C	N	S		A	
6.26	pilots may obtain approval for special maneuvers such as station keeping with reduced spacing.!!Key Words: station keeping	C	N	S		A	

Level I #	ATS 2005 Statement (Level I Need)	C	N	S	W	A	M
7.65	User flexibility is significantly expanded by advance information about demand and capacity … revising their plans in a timely manner.!!Key Words: flexibility	C				A	

Table 3.3.3.4-3 LVTO Functional Requirement Verification Definitions

Insp	Inspection	Verification is based the determination that the system specification includes the requirement, the system was developed to include the capabilities of the requirement, and an examination of the system shows that the capabilities to meet the requirement were included. Results show that the required capability is in the system to the extent verifiable by inspection only.
A/S	Analysis / Simulation	Verification is based on analysis of the developed system capability. This analysis includes desk checking of characteristics and simulation. Operation of the system is not required. Results show that the specified capability, to the extent possible using analysis and simulation, was developed in the system in such a way the required capability is achievable.
Lab	Laboratory Test	Verification is based on operation of the system (in part or as a whole) in a laboratory environment. Some laboratory equipment may be used in place of operational equipment. Results show that specific required capabilities are achievable using the developed system (in part or as a whole) with laboratory instruments used for measurement and stimulation.
Demo	Demonstration Test	Verification is based on operation of the system (in part or as a whole) using operational equipment. Laboratory equipment is not used. Results show that the selected capability is observed using system components.
Field	Field Test	Verification is based on operation of the system using operational equipment in an operational environment. Results show that the selected capability is repeatedly demonstrable in an operational environment
Validation	Validation Test	Verification is based on operation of the system using operational equipment in an operational environment. Results of the comprehensive evaluation of thorough performance testing show that the full scope of the capability is achieved and is repeatable.

Table 3.3.3.4-4 LVTO Functional Requirement Verification Procedures

Number	Functional Requirement	Insp	A/S	Lab	Demo	Field
3C-1	The LVTO shall receive own aircraft position and velocity from GPS which may be augmented with LAAS and/or WAAS and shall broadcast ACID, Position, and velocity in the standardized ADS-B formats.			X	X	X
3C-2	The LVTO shall receive the ADS-B states of other aircraft.				X	X
3C-3	The LVTO shall receive TIS data link messages via the appropriate data link and shall distribute these messages to the display generator and to the on-board TIS/ADS-B Correlator and Coordinate Conversion processor.			X		X
3C-4	The LVTO shall receive station-keeping clearances from the controller via data link and shall distribute these messages to the LVTO station keeping aid.			X	X	X
3C-5	Voice communications shall be available between the pilot and the controller however this is not considered an LVTO functional requirement.	X			X	
3C-6	The LVTO shall communicate operation in a degraded navigational mode to the ground based ATC system when this situation occurs.		X	X		
3N-1	The LVTO system shall receive its navigational position from GPS, when available.				X	X
3N-2	The navigational position information shall be able to receive WAAS and LAAS satellite information, when available.			X		
3N-3	If GPS is not available, the aircraft shall use an appropriate area navigation instrument to provide an input to the LVTO processor.			X	X	
3S-1	LVTO shall receive ADS-B and TIS aircraft states from the ADS-B air-to-air broadcasts of aircraft state and from the TIS discrete data link messages.			X	X	X
3S-2	LVTO shall correlate the received TIS aircraft states and the ADS-B aircraft states in order to eliminate duplicate target reports on the same aircraft.			X		
3S-3	LVTO shall broadcast its own aircraft state for use by the ground ATC surveillance system and for air-to-air surveillance by other properly equipped aircraft.			X		X
3A-1	LVTO shall automatically correlate the received TIS aircraft states and the ADS-B aircraft states in order to eliminate duplicate target reports on the same aircraft.			X		
3A-2	LVTO shall automatically convert all aircraft states into own aircraft relative coordinates.		X	X		X
3A-3	LVTO shall automatically process all display inputs from the pilot. These inputs shall at a minimum include control of display brightness, contrast, location of own aircraft on the display, and on/off controls.	X		X	X	
3A-4	LVTO shall automatically process and display station keeping clearances and other ATC data link messages.		X			

Number	Functional Requirement	Insp	A/S	Lab	Demo	Field
3C-1	The LVTO shall receive own aircraft position and velocity from GPS which may be augmented with LAAS and/or WAAS and shall broadcast ACID, Position, and velocity in the standardized ADS-B formats.			X	X	X
3C-2	The LVTO shall receive the ADS-B states of other aircraft.				X	X
3C-3	The LVTO shall receive TIS data link messages via the appropriate data link and shall distribute these messages to the display generator and to the on-board TIS/ADS-B Correlator and Coordinate Conversion processor.			X		X
3C-4	The LVTO shall receive station-keeping clearances from the controller via data link and shall distribute these messages to the LVTO station keeping aid.			X	X	X
3C-5	Voice communications shall be available between the pilot and the controller however this is not considered an LVTO functional requirement.	X			X	
3C-6	The LVTO shall communicate operation in a degraded navigational mode to the ground based ATC system when this situation occurs.		X	X		
3N-1	The LVTO system shall receive its navigational position from GPS, when available.				X	X
3N-2	The navigational position information shall be able to receive WAAS and LAAS satellite information, when available.			X		
3N-3	If GPS is not available, the aircraft shall use an appropriate area navigation instrument to provide an input to the LVTO processor.			X	X	
3S-1	LVTO shall receive ADS-B and TIS aircraft states from the ADS-B air-to-air broadcasts of aircraft state and from the TIS discrete data link messages.			X	X	X
3S-2	LVTO shall correlate the received TIS aircraft states and the ADS-B aircraft states in order to eliminate duplicate target reports on the same aircraft.			X		
3S-3	LVTO shall broadcast its own aircraft state for use by the ground ATC surveillance system and for air-to-air surveillance by other properly equipped aircraft.			X		X
3A-1	LVTO shall automatically correlate the received TIS aircraft states and the ADS-B aircraft states in order to eliminate duplicate target reports on the same aircraft.			X		
3A-2	LVTO shall automatically convert all aircraft states into own aircraft relative coordinates.		X	X		X
3A-3	LVTO shall automatically process all display inputs from the pilot. These inputs shall at a minimum include control of display brightness, contrast, location of own aircraft on the display, and on/off controls.	X		X	X	
3A-4	LVTO shall automatically process and display station keeping clearances and other ATC data link messages.		X			
3C-1	The LVTO shall receive own aircraft position and velocity from GPS which may be augmented with LAAS and/or WAAS and shall broadcast ACID, Position, and velocity in the standardized ADS-B formats.			X	X	X
3C-2	The LVTO shall receive the ADS-B states of other aircraft.				X	X

Number	Functional Requirement	Insp	A/S	Lab	Demo	Field
3C-3	The LVTO shall receive TIS data link messages via the appropriate data link and shall distribute these messages to the display generator and to the on-board TIS/ADS-B Correlator and Coordinate Conversion processor.			X		X
3C-4	The LVTO shall receive station-keeping clearances from the controller via data link and shall distribute these messages to the LVTO station keeping aid.			X	X	X
3C-5	Voice communications shall be available between the pilot and the controller however this is not considered an LVTO functional requirement.	X			X	
3C-6	The LVTO shall communicate operation in a degraded navigational mode to the ground based ATC system when this situation occurs.		X	X		
3N-1	The LVTO system shall receive its navigational position from GPS, when available.				X	X
3N-2	The navigational position information shall be able to receive WAAS and LAAS satellite information, when available.			X		
3N-3	If GPS is not available, the aircraft shall use an appropriate area navigation instrument to provide an input to the LVTO processor.			X	X	
3S-1	LVTO shall receive ADS-B and TIS aircraft states from the ADS-B air-to-air broadcasts of aircraft state and from the TIS discrete data link messages.			X	X	X
3S-2	LVTO shall correlate the received TIS aircraft states and the ADS-B aircraft states in order to eliminate duplicate target reports on the same aircraft.			X		
3S-3	LVTO shall broadcast its own aircraft state for use by the ground ATC surveillance system and for air-to-air surveillance by other properly equipped aircraft.			X		X
3A-1	LVTO shall automatically correlate the received TIS aircraft states and the ADS-B aircraft states in order to eliminate duplicate target reports on the same aircraft.			X		
3A-2	LVTO shall automatically convert all aircraft states into own aircraft relative coordinates.		X	X		X
3A-3	LVTO shall automatically process all display inputs from the pilot. These inputs shall at a minimum include control of display brightness, contrast, location of own aircraft on the display, and on/off controls.	X		X	X	
3A-4	LVTO shall automatically process and display station keeping clearances and other ATC data link messages.		X			
3A-5	LVTO may, as an option, incorporate an n automated station keeping aid to assist the pilot in performing accurate station keeping maneuvers. This aid will be incorporated into the CDTI if it is made available.		X			
3A-6	LVTO shall automatically inform the ground based ATC system of operation in a degraded mode.		X	X		
3OM-1	The LVTO system shall monitor the inputs received from the navigational source as well as to determine the integrity/reasonableness of the aircraft state and data link messages received.			X		

Number	Functional Requirement	Insp	A/S	Lab	Demo	Field
3OM-2	The LVTO system shall monitor its own operational status and shall automatically report any malfunctions to the ATC system.			X		

3.4 Enhanced See and Avoid (ESA) Functional Specification

This functional specification for the ESA consists of detailed description of the ESA system concept, a presentation of the ESA functional requirements for each of the major ATC functions (i.e., Communications, Navigation, Surveillance, Weather, Automation, and Maintenance and Operations), and an elaboration of the ESA functional design including functional flow diagrams and interface requirements.

3.4.1 ESA System Concept

The ESA concept consists of a definition of the operational concept, the capabilities, and the expected benefits. Within the operational concept, the ESA mission and modes of operation are also defined. Figure 3.4.1-1 illustrates the ESA concept and shows that it is totally contained on-board the aircraft and consists primarily of surveillance data collection, processing, and display to the pilot on-board using CDTI or any suitable CD display. Interface with the ground based ATC system data link processor is also required in order to receive messages and alerts from the ATC automation system, TIS, and the air traffic controller.

ESA process traffic surveillance data from the primary sources the ADS-B, TIS, and using TIS-B. Aircraft specific warnings of conflict with other TIS or TIS-B aircraft may also be sent directly to pilots via a discrete data link.

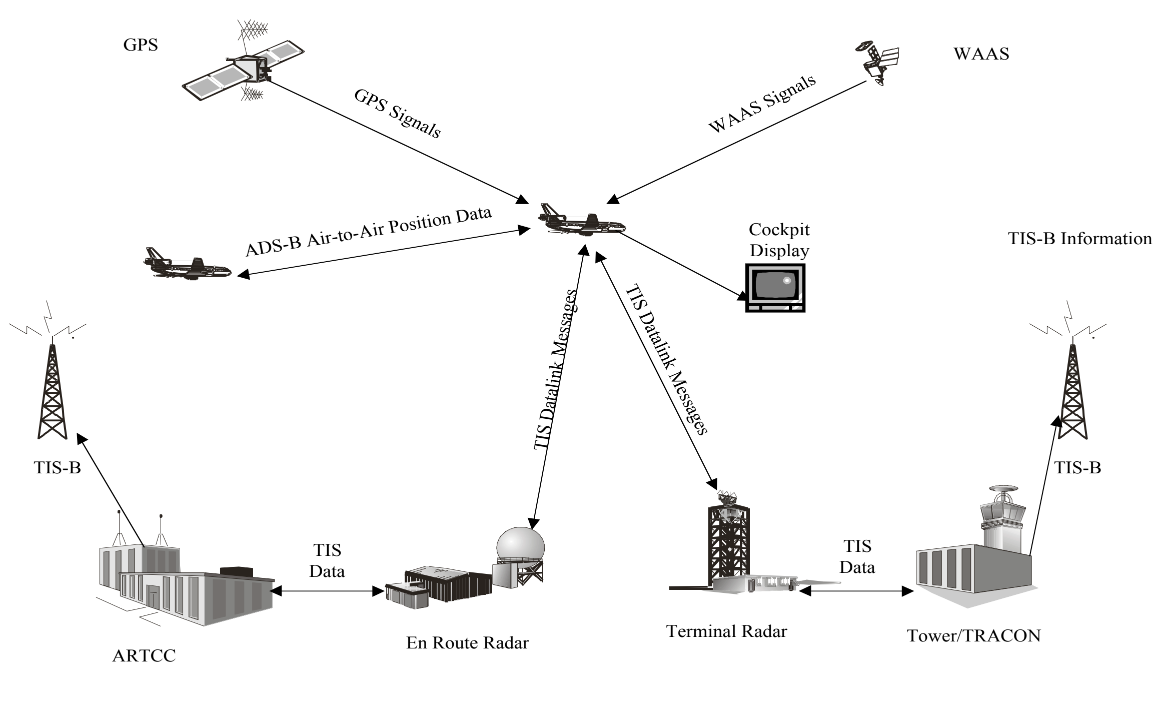


Figure 3.4.1-1 ESA System Concept

3.4.1.1 ESA Operational Concept

The ESA operational concept is to provide traffic information, electronically, in the cockpit using CDTI display with ADS-B surveillance information received on squitter messages from the nearby aircraft, or TIS/ TIS-B surveillance information from the ground based radar-tracking system. This capability will increase pilot situation awareness and improve airport capacity. The conflict information is provided in the cockpit via the ground based ATC Automation System.

The ESA concept consists of non-control advisory information needed by pilots to operate more safely and efficiently. ESA uses ground based data surveillance track data transmissions fed from TIS/TIS-B and uses ADS-B broadcasts of aircraft state to display the position of surrounding aircraft on the cockpit display. ESA will provide increased access to airspace and a reduction in flight times, delays, and distance flown.

3.4.1.1.1 Mission

There are limitations with today's system of see-and-be-seen. This results in safety and efficiency issues, especially at non-tower airports. It is not cost beneficial for most general aviation aircraft to carry TCAS equipment and they are not required to do so. However, it is advantageous to increase safety for all aircraft by providing enhanced situational awareness of the surrounding trafficespecially in instrumental meteorological conditions (IMC) or for IFR flights. Thus, the mission of ESA may be stated as:

"Improve flight safety and efficiency through increased situational awareness of nearby traffic"

3.4.1.1.2 Modes of Operation

There are two basic modes of operation for the ESA:

- Collection, processing and display of ADS-B, TIS or TIS-B surveillance data in the cockpit
- Situation alert mode to increase pilot awareness of proximate traffic

3.4.1.2 ESA Capabilities

Implementation of ESA provides the following operational capabilities:

- Enhance visual acquisition of other traffic in the VFR traffic pattern at uncontrolled (non-tower) airports using ADS-B
- Retransmit position reports from all pertinent aircraft from the Traffic Information Service back to the cockpit
- Use ADS-B/CDTI to provide traffic and/or conflict information to the pilot
- Use TIS or TIS-B to enhance the traffic information to the pilot.

3.4.1.3 ESA Benefits

ESA is expected to produce benefits in the following areas of safety, efficiency, flexibility, and capacity:

- Improved traffic situation awareness in all airspace resulting in greater safety;
- Improved probability of visual acquisition;
- Enhance conflict detection and collision avoidance.

3.4.2 ESA Functional Requirements

The functional requirements for ESA have been developed by first considering the ESA capabilities and then determining the relevant operational needs as stated in the ATS 2005 CONOPS Narrative. The operational capabilities and needs were then analyzed to determine the ATC functions, which were required to satisfy the need. These ESA operational requirements are presented as requirements traceability matrices in Section 3.4.3.4 and are summarized for each of the major ATC functions in the following paragraphs.

3.4.2.1 Communications

The communications requirements for ESA are primarily associated with transmitting and receiving ADS-B and TIS-B broadcasts of aircraft state and with receiving TIS messages over a data link. The TIS messages consist of aircraft state information, other TIS commands and alerts. An analysis of the detailed communications requirements contained in the requirement traceability matrix (Section 3.4.3.4) coupled with an examination of the required capabilities results in the following set of communications functional requirements:

1. The ESA shall receive own aircraft position and velocity from GPS which may be augmented with LAAS and/or WAAS and shall broadcast ACID, Position, and velocity in the standardized ADS-B formats
2. The ESA shall receive the ADS-B states of other aircraft
3. The ESA shall receive the TIS-B states of other aircraft
4. The ESA shall receive TIS data link messages via the appropriate data link and shall distribute these messages to the display generator and to the on-board TIS/TIS-B/ADS-B Correlator and Coordinate Conversion processor.
5. The ESA shall receive conflict alert and other messages from ATC automation system via data link and shall distribute these messages to the ESA display generator.
6. Voice communications shall be available between the pilot and the controller however this is not considered an ESA functional requirement
7. The ESA shall communicate operation in a degraded navigational mode to the ground based ATC system when this situation occurs.

3.4.2.2 Navigation

The ESA requires precise navigational information that uses satellite or augmented satellite information to derive position. An analysis of the detailed navigational requirements contained in the requirement traceability matrix results in the following set of navigational functional requirements:

1. The ESA system shall receive its navigational position from GPS, when available.

2. The navigational position information shall be able to receive WAAS and LAAS satellite information, when available.
3. If GPS is not available, the aircraft shall use an appropriate area navigation instrument to provide an input to the ESA processor.

3.4.2.3 Surveillance

ESA has no direct ATC surveillance requirements although it is assumed that the aircraft is under ATC surveillance and control. ESA does however depend upon air-to-air surveillance, which is supplemented with TIS and TIS-B aircraft states from the ground. This is necessary in order to assure that non-ADS-B-equipped aircraft will also be under the surveillance of the pilot using the CDTI. An analysis of the detailed surveillance requirements contained in the requirement traceability matrix (Section 3.4.3.4) coupled with an examination of the required ESA capabilities results in the following set of airborne surveillance functional requirements:

1. ESA shall receive ADS-B, TIS-B and TIS aircraft states from the ADS-B air-to-air broadcasts of aircraft state, the ground based TIS-B broadcasts of aircraft state, and from the TIS discrete data link messages.
2. ESA shall correlate the received TIS aircraft states and the TIS-B and ADS-B aircraft states in order to eliminate duplicate target reports on the same aircraft
3. ESA shall broadcast its own aircraft state for use by the ground ATC surveillance system and for air-to-air surveillance by other properly equipped aircraft.

3.4.2.4 Weather

ESA does not have any directly related functional requirements in the weather area.

3.4.2.5 Automation

The automation functions required by ESA involve the processing of: ADS-B, TIS-B and TIS aircraft state information; the development of appropriate commands to drive the CDTI display; and, a conflict alert function transmitted by the ground based ATC automation system. ATC automation is not considered part of the ESA system but it is recognized that it must provide inputs to the ESA using the TIS and data link. Analysis of the detailed automation requirements contained in the requirement traceability matrix (Section 3.4.3.4) coupled with an examination of the required ESA capabilities results in the following set of airborne automation functional requirements:

1. ESA shall automatically correlate the received TIS, TIS-B, and ADS-B aircraft states in order to eliminate multiple target reports on the same aircraft
2. ESA shall automatically convert all aircraft states into own aircraft relative coordinates
3. ESA shall automatically process all display inputs from the pilot. These inputs shall at a minimum include control of display brightness, contrast, location of own aircraft on the display, and on/off controls.
4. ESA shall automatically process and display conflict alerts and other ATC data link messages
5. ESA shall automatically generate alerts to the pilot concerning potentially dangerous traffic

6. ESA shall automatically inform the ground based ATC system of operation in a degraded mode

3.4.2.6 Operations and Maintenance

1. The ESA system shall monitor the inputs received from the navigational source as well as to determine the integrity/reasonableness of the aircraft state and data link messages received.
2. The ESA system shall monitor its own operational status and shall automatically report any malfunctions to the ATC system.

3.4.3 ESA Functional Design

This section describes the ESA system design that satisfies functional requirements and capabilities discussed in Sections 3.4.2 and 3.4.2. The figure 3.4.3-1 represents a functional flow of the ESA system.

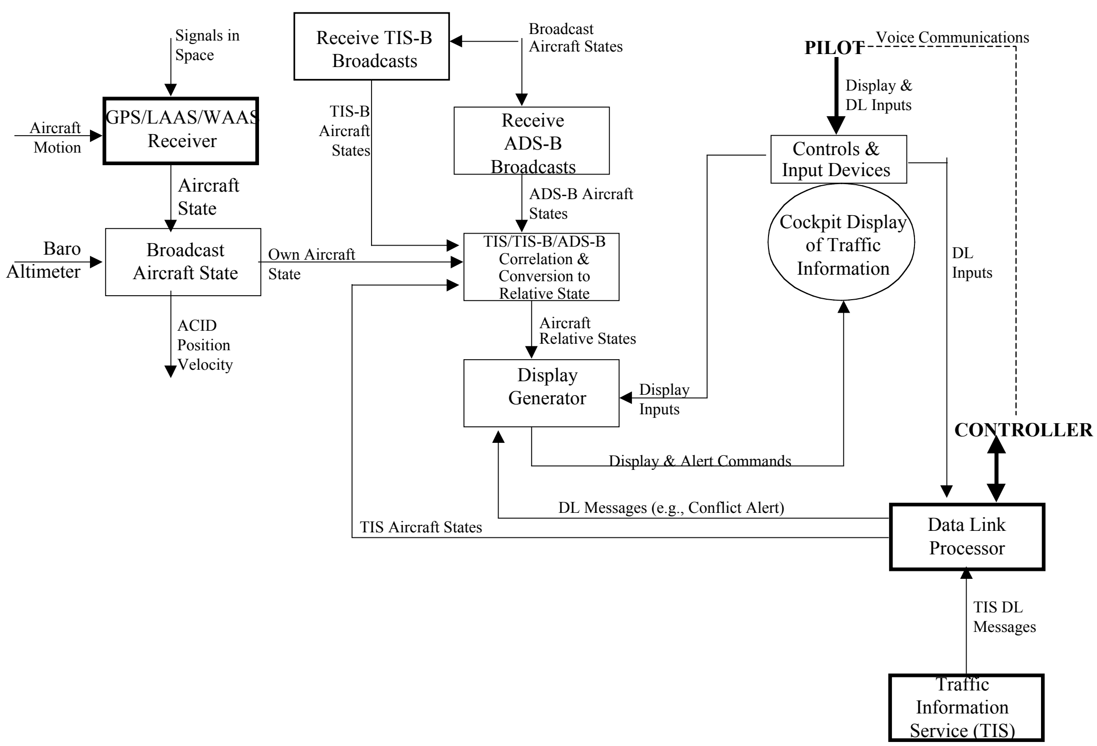


Figure 3.4.3-1 ESA Functional Block Diagram

The functional design for the ESA begins with an assumption that ADS-B surveillance, cockpit display CDTI or equivalent, ADS-B transmitter/data link/avionics, and GPS input data are available. Other supporting systems are TIS and/or TIS-B with a discrete and broadcast mode up-link respectively.

3.4.3.1 System Functional Relationships

Traffic information is received, processed, and displayed in the cockpit to provide a situational awareness to the pilot of the surrounding traffic for improve see-and-be-seen capability. In the cockpit display mode, a continuous traffic situation is available to the pilot for increased confidence, visual enhancement during marginal conditions, to maintain visual surveillance during a brief coasting interval while reacquiring the target and to help new target acquisition. Aircraft specific ESA messages such as traffic alerts are transmitted to the aircraft using a discrete address data link messaging capability.

ESA develops the following products from the received information:

- A display of nearby targets in the cockpit with target ID, position, and velocity
- Aural and visual alarm on proximate traffic

ESA begins by determining own aircraft state from the GPS receiver and then broadcasting this position using the ADS-B format. The state of own aircraft is used by ESA as the basis for converting the TIS, TIS-B and ADS-B received aircraft states into own aircraft centered coordinates. ESA also correlates the TIS, TIS-B and ADS-B aircraft states in order to remove duplicated targets (e.g. the same aircraft may be reported by TIS and ADS-B). Once targets are correlated and converted to own aircraft state they are forwarded to the Display and Alert generator. Alerts are developed for proximate traffic that could be potentially dangerous. Alert messages are also received from ATC automation and are correlated with the ESA developed alerts. The aircraft states and alerts are then displayed to the pilot in aircraft centered or offset coordinates depending on pilot display input.

The multifunctional cockpit display may share common display screen with other operational enhancements either by integrating ESA information with the rest of the display features or by overlaying the screen using mode switching. Primary surveillance data is obtained from the ADS-B broadcast. This surveillance is supported by the ground derived radar data up-linked to the cockpit.

3.4.3.2 Interface Requirements

Observing ESA functional diagram, there are five inputs to generate pilot display and enhance the pilot situational awareness. These are:

- ADS-B input consisting of aircraft ID, position and velocity.
- TIS/TIS-B radar surveillance data with conflict prediction data referenced to the to the own aircraft
- GPS derived navigation position data for own aircraft
- Data link for the exchange of traffic and alert information

Own aircraft position will require a GPS receiver unless and acceptable alternative is already available. TIS service will deliver already processed aircraft track information to the aircraft using an acceptable data link. . The TIS-B information will be broadcast to all aircraft and processed on-board.

3.4.3.2.1 Internal Interfaces

Internal interfaces include:

- Pilot/Display –On/Off Control
- Ground/Aircraft – compatible transmitters, receivers and message formats
- Navigator/Processor/Display – compatible message format and display driver

3.4.3.2.2 External Interfaces

External interface include ESA interface with:

- Data Link Message Delivery System – one-way interface for data collection
- TIS and TIS/B for surrounding aircraft state.

3.4.3.3 Human Factors Considerations

The human factor considerations for ESA primarily revolve around the design of the ESA display and the graphical depiction of the location of traffic and alert information relative to own aircraft. This may be complicated by the need to use a multifunction display that will accommodate the display requirements of many of the other free flight operational enhancements. In addition, pilot interface with the display must include appropriate controls such as zoom, brightness, and contrast, alert off control, display on/off controls, and display mode controls. If using a multifunction display, care must be taken to include features such that if an alert comes from a mode not presently being displayed, it will still be made known to the pilot. The human factor design of this multifunction display must consider the low-end general aviation user.

3.4.3.4 ESA Requirements Traceability Matrices

Three aspects of requirement traceability are provided in this section. The first provides traceability between the ESA capabilities and the operational requirements as stated in the ATS 2005 CONOPS Narrative and the Joint Government/Industry Operational Concept. The second provides the functional allocation of the operational requirements derived from the ATS 2005 Narrative to the major ATC functions (i.e., communications, surveillance, navigation, weather, automation, maintenance and operations). The third aspect provides recommended requirements validation methodology for each of the functional requirements identified in Section 3.4.2.

3.4.3.4.1 Capabilities to CONOPS Traceability

These operational requirements, see Table 3.4.3.4-1, are derived from the ATS 2005 CONOPS Narrative. They have been developed based upon key word searches of the ATS 2005 Operational Needs database. The key words used in these searches were based on the ESA capability description obtained from the RTCA Roadmap. In addition, the capabilities are also traced to each of the needs identified in the Joint Government Industry CONOPS published by RTCA. Appendix B of the RTCA Operational Enhancement Roadmap was used to accomplish this traceability.

3.4.3.4.2 Operational to Functional Requirement Traceability

Each ESA operational requirement is related to at least one ESA capability. Table 3.4.3.4-2 provides the functional allocation of the set of ESA operational requirements. It must be noted that not all requirements obtained in this manner are directly related to the ESA and that analysis of these requirements coupled with the definition of capabilities has resulted in the statement of the functional requirements provided in section 3.4.2 of this specification.

3.4.3.4.3 Procedures for Functional Requirement Verification

This table provides a list of the functional requirements in each functional area and will provide a recommended requirement verification procedure in Table 3.4.3.4-4. These procedures will include the methods of Inspection, Analysis/Simulation, Laboratory Tests, Demonstration, and/or Operational Tests including Flight Tests. Definitions for each of these verification methods are included below.

Table 3.4.3.4-1 ESA Capabilities and Requirements

	OPERATIONAL ENHANCEMENT Operational Capabilities	Key Words	Level 1 Narrative Operational Requirement	Joint Industry/Government CONOPS Capabilities Appendix B
4	**Enhanced Visual Operations and Situational Awareness**			**B4**
4.1	Position reports for all pertinent aircraft retransmitted from the Traffic Information Service back to the cockpit.	Position	3.30, 4.12, 5.12, 5.14, 5.41, 6.6, 6.7, 6.24	4.1, 4.2, 4.2.1
4.2	Use ADS-B and CDTI to provide traffic and/or conflict information to the pilot.	Traffic (or) Conflict	4.12, 4.22, 4.24, 5.41, 6.23, 6.25, 6.27	4.1, 4.2, 4.2.1, 5.2, 5.2.2
4.3	Use TIS or TIS-B to enhance the traffic information to the pilot.	Traffic (or) Position	3.30, 4.12, 4.24, 5.14, 5.41, 6.23, 6.24	4.1, 4.2, 4.2.1

Table 3.4.3.4-2 ESA Functional Allocation of Operational Requirements

Level I #	ATS 2005 Statement (Level I Need)	C	N	S	W	A	M
3.30	Service providers can display satellite-derived position data transmitted by selected flights upon request, while ground-based surveillance data is shared with users as a safety enhancement for preventing incursions.	C		S		A	
4.12	Satellite-based position data, broadcast by properly equipped aircraft, are used in cockpit traffic displays to increase the pilots' situation awareness for aircraft-to-aircraft separation. These avionics allow an increasingly frequent transfer of responsibility for separation assurance to the flight deck for some types of operations.!!Key Words: self separation!!	C	N	S		A	
4.22	Aircraft-to-aircraft separation remains the responsibility of service providers … in most traffic situations, it remains solely their responsibility.	C		S		A	
4.24	The increased use of this shared responsibility is made feasible through traffic displays on the flight deck, and rules, procedures, and training programs that have modified the roles and responsibilities of users and service providers.					A	M
5.12	En route surveillance is accomplished through a combination of primary radar, beacon interrogation, and broadcasts of aircraft position and speed.	C	N	S		A	
5.14	An increasing number of aircraft are equipped with satellite based navigation, digital communications, and the capability to automatically transmit position data.	C	N	S		A	
5.41	For VFR aircraft automatically reporting their satellite-derived positions … coupled with access to the flight's data via the NAS-wide information system, reduces the workload associated with providing traffic advisories to uncontrolled aircraft.!!Key Words: traffic advisories	C	N	S		A	M
6.6	Satellite navigation systems and datalink allow more accurate and frequent traffic position updates; datalink and expanded radio coverage provide direct air-to-ground communications (both digital and voice).!!Key Words: navigation	C	N	S		A	
6.7	Real time position data and continuously updated trajectory projections virtually eliminate manual control procedures in Oceanic airspace … Oceanic separation standards and procedures are derived from radar control techniques.	C		S		A	
6.23	Pilots have situation awareness of nearby traffic through a cockpit display of traffic information.!!Key Words: CDTI	C		S		A	
6.24	Aircraft position updates are supplied by the aircraft's broadcast of satellite navigation-derived position data transmissions.!!Key Words: position reports	C	N	S		A	
6.25	pilots may coordinate with service providers for clearance to conduct specified maneuvers while the pilot's view of nearby traffic supplements the service provider's big picture of longer term traffic flow.	C	N	S		A	

6.27	The pilot’s ability to support climbs, descents, crossing and merging routes is supplemented by the service provider’s conflict probe decision support system.!!Key Words: conflict Probe	C	N	S		A	

Table 3.4.3.4-3 ESA Functional Requirement Verification Definitions

Insp	Inspection	Verification is based the determination that the system specification includes the requirement, the system was developed to include the capabilities of the requirement, and an examination of the system shows that the capabilities to meet the requirement were included. Results show that the required capability is in the system to the extent verifiable by inspection only.
A/S	Analysis / Simulation	Verification is based on analysis of the developed system capability. This analysis includes desk checking of characteristics and simulation. Operation of the system is not required. Results show that the specified capability, to the extent possible using analysis and simulation, was developed in the system in such a way the required capability is achievable.
Lab	Laboratory Test	Verification is based on operation of the system (in part or as a whole) in a laboratory environment. Some laboratory equipment may be used in place of operational equipment. Results show that specific required capabilities are achievable using the developed system (in part or as a whole) with laboratory instruments used for measurement and stimulation.
Demo	Demonstration Test	Verification is based on operation of the system (in part or as a whole) using operational equipment. Laboratory equipment is not used. Results show that the selected capability is observed using system components.
Field	Field Test	Verification is based on operation of the system using operational equipment in an operational environment. Results show that the selected capability is repeatedly demonstrable in an operational environment
Validation	Validation Test	Verification is based on operation of the system using operational equipment in an operational environment. Results of the comprehensive evaluation of thorough performance testing show that the full scope of the capability is achieved and is repeatable.

Table 3.4.3.4-4 ESA Functional Requirement Verification Procedures

Number	Functional Requirement	Insp	A/S	Lab	Demo	Field
4C-1	The ESA shall receive own aircraft position and velocity from GPS which may be augmented with LAAS and/or WAAS and shall broadcast ACID, Position, and velocity in the standardized ADS-B formats.			X	X	X
4C-2	The ESA shall receive the ADS-B states of other aircraft.				X	X
4C-3	The ESA shall receive the TIS-B states of other aircraft.				X	X
4C-4	The ESA shall receive TIS data link messages via the appropriate data link and shall distribute these messages to the display generator and to the on-board TIS/TIS-B/ADS-B Correlator and Coordinate Conversion processor.			X		X
4C-5	The ESA shall receive conflict alert and other messages from the ATC automation system via data link and shall distribute these messages to the ESA display generator.			X	X	
4C-6	Voice communications shall be available between the pilot and the controller however this is not considered an ESA functional requirement.	X			X	
4C-7	The ESA shall communicate operation in a degraded navigational mode to the ground based ATC system when this situation occurs.		X	X		
4N-1	The ESA system shall receive its navigational position from GPS, when available.				X	X
4N-2	The navigational position information shall be able to receive WAAS and LAAS satellite information, when available.			X		
4N-3	If GPS is not available, the aircraft shall use an appropriate area navigation instrument to provide an input to the ESA processor.			X	X	
4S-1	ESA shall receive ADS-B, TIS-B and TIS aircraft states from the ADS-B air-to-air broadcasts of aircraft state, the ground based TIS-B broadcasts of aircraft state, and from the TIS discrete data link messages.			X	X	X
4S-2	ESA shall correlate the received TIS aircraft states and the TIS-B and ADS-B aircraft states in order to eliminate duplicate target reports on the same aircraft.			X		
4S-3	ESA shall broadcast its own aircraft state for use by the ground ATC surveillance system and for air-to-air surveillance by other properly equipped aircraft.			X		X
4A-1	ESA shall automatically correlate the received TIS, TIS-B, and ADS-B aircraft states in order to eliminate multiple target reports on the same aircraft.		X	X		X
4A-2	ESA shall automatically convert all aircraft states into own aircraft relative coordinates.			X	X	
4A-3	ESA shall automatically process all display inputs from the pilot. These inputs shall at a minimum include control of display brightness, contrast, location of own aircraft on the display, and on/off controls.	X		X	X	

Number	Functional Requirement	Insp	A/S	Lab	Demo	Field
4A-4	ESA shall automatically process and display conflict alerts and other ATC data link messages.			**X**	**X**	
4A-5	ESA shall automatically inform the ground based ATC system of operation in a degraded mode.		**X**	**X**		
4OM-1	The ESA system shall monitor the inputs received from the navigational source as well as to determine the integrity/reasonableness of the aircraft state and data link messages received.			**X**		
4OM-2	The ESA system shall monitor its own operational status and shall automatically report any malfunctions to the ATC system.			**X**		

3.5 En Route Air-to-Air (ERA/A) Functional Specification

This functional specification for En Route Air to Air operations (ERA/A) consists of a detailed description of the ERA/A concept, a presentation of the ERA/A functional requirements for each of the major ATC functions (i.e., Communications, Navigation, Surveillance, Weather, Automation and Maintenance and Operations) and an elaboration of the ERA/A functional design including flow diagrams and interface requirements.

3.5.1 ERA/A System Concept

The ERA/A concept consists of a definition of the operational concept, the capabilities and the expected benefits. Within the operational concept, the ESAA mission and modes of operation are also defined. Figure 3.5.1-1 illustrates the ERA/A concept. The ERA/A system primarily consists of data collection of surveillance data from proximate traffic, the dissemination of position reports and the graphical representation of the surrounding air traffic. The ERA/A system uses ADS-B position reports, data link and a cockpit display of surrounding traffic.

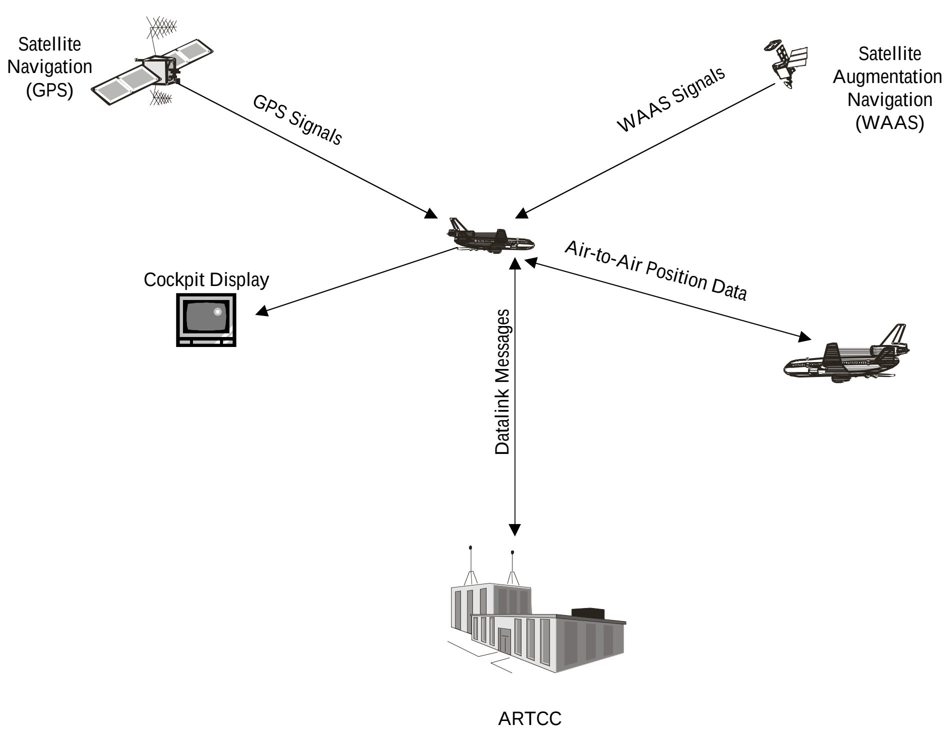


Figure 3.5.1-1 ERA/A System Concept

3.5.1.1 ERA/A Operational Concept

The use of ADS-B, CDTI, data link and related technologies have the potential for delegation of separation authority to the cockpit from the service provider in certain traffic situations. The aircraft broadcasts its position and receives the position reports from other aircraft. The position of the surrounding aircraft traffic is displayed on the pilot's graphical display relative to the aircraft's own position. The implementation of the ERA/A will increase access to airspace, reduce flight delays and distances flown, increase predictability of flight times and distances flown and increase flexibility in flights flown.

3.5.1.1.1 Mission

The lack of and/or limitations of surveillance data limit the efficiency of separation standards and procedures. With the use and implementation of ADS-B and CDTI, the delegation of separation authority may be transferred from the service provider to the pilot, thus increasing efficiency. The mission of ERA/A can be stated as the following:

Improve flight safety and airspace access through increased situational awareness of proximate traffic

3.5.1.1.2 Modes of Operation

ERA/A has two basic modes of operation:

- Situational awareness mode: In the situational awareness mode, the position of the aircraft relative to surrounding aircraft is displayed to the pilot on a graphical display.
- Broadcast Mode: In the broadcast mode, a common frequency is used to broadcast ADS-B messages to all aircraft within reception range.

3.5.1.2 ERA/A Capabilities

The implementation of cost effective ERA/A provides the following operational capabilities:

- Use air-to-air ADS-B position reports for station-keeping and self-separation by ADS-B equipped aircraft
- Assist pilot in maintaining situational awareness, acquiring visually proximate traffic acquisition and enhancing visual separation in radar and non-radar airspace
- Support limited station-keeping maneuvers
- Delegate separation assurance to pilots by service providers for appropriately equipped pairs of crossing aircraft

3.5.1.3 ERA/A Benefits

The ERA/A system is expected to produce the following benefits:

- Increase access to airspace
- Reduce in flight delays and distances flown

- Increase predictability of flight times and distances flown
- Increase flexibility in route flown

3.5.2 ERA/A Functional Requirements

The functional requirements for ERA/A have been developed by first considering the ERA/A capabilities and then determining the relevant operational needs as stated in the ATS 2005 CONOPS Narrative. The operational capabilities and needs were then analyzed to determine the ATC functions, which were required to satisfy the need. These ERA/A operational requirements are presented as requirements traceability matrices in Section 3.5.3.4 and are summarized for each of the major ATC functions in the following paragraphs.

3.5.2.1 Communications

The communications requirements for ERA/A are primarily associated with transmitting and receiving ADS-B broadcasts of aircraft state. In addition, data link and voice communications with the ground-based system are assumed. The ERA/A enhancement is expected to process all ERA/A related data link messages from the ground based ATC system including delegation of separation assurance responsibility to the pilot, station keeping clearances, and other related messages. An analysis of the detailed communications requirements contained in the requirement traceability matrix (Section 3.5.3.4) coupled with an examination of the required capabilities results in the following set of communications functional requirements:

1. The ERA/A shall receive own aircraft position and velocity from GPS which may be augmented with LAAS and/or WAAS and shall broadcast ACID, Position, and velocity in the standardized ADS-B formats
2. The ERA/A shall receive the ADS-B states of other aircraft
3. The ERA/A shall receive delegated separation assurance, station keeping and other messages from the ATC automation system via data link and shall distribute these messages to the ERA/A display generator.
4. Voice communications shall be available between the pilot and the controller however this is not considered an ERA/A functional requirement
5. The ERA/A shall communicate operation in a degraded navigational mode to the ground based ATC system when this situation occurs.

3.5.2.2 Navigation

The ERA/A requires precise navigational information that uses satellite or augmented satellite information to derive position. An analysis of the detailed navigational requirements contained in the requirement traceability matrix results in the following set of navigational functional requirements:

1. The ERA/A system shall receive its navigational position from GPS, when available.
2. The navigational position information shall be able to receive WAAS and LAAS satellite information, when available.
3. If GPS is not available, the aircraft shall use an appropriate area navigation instrument to provide an input to the ERA/A processor.

3.5.2.3 Surveillance

ERA/A has no direct ATC surveillance requirements although it is assumed that the aircraft is under ATC surveillance and control. ERA/A does however depend upon air-to-air ADS-B surveillance. An analysis of the detailed surveillance requirements contained in the requirement traceability matrix (Section 3.5.3.3) coupled with an examination of the required ERA/A capabilities results in the following set of airborne surveillance functional requirements:

1. ERA/A shall receive ADS-B aircraft states from the ADS-B air-to-air broadcasts of aircraft state.
2. ERA/A shall broadcast its own aircraft state for use by the ground ATC surveillance system and for air-to-air surveillance by other properly equipped aircraft.

3.5.2.4 Weather

ERA/A does not have any directly related functional requirements in the weather area

3.5.2.5 Automation

The automation functions required by ERA/A involve the processing of: ADS-B aircraft state information; the development of appropriate commands to drive the CDTI display; and, processing and display of datalink messages including delegation of separation assurance and station keeping messages transmitted by the ground based ATC automation system or by controller input. ATC automation is not considered part of the ERA/A system but it is recognized that it must provide inputs to the ERA/A using the data link. Analysis of the detailed automation requirements contained in the requirement traceability matrix (Section 3.5.3.3) coupled with an examination of the required ERA/A capability results in the following set of airborne automation functional requirements:

1. ERA/A shall automatically convert all ADS-B aircraft states into own aircraft relative coordinates
2. ERA/A shall automatically process all display inputs from the pilot. These inputs shall at a minimum include control of display brightness, contrast, location of own aircraft on the display, and on/off controls.
3. ERA/A shall automatically process and display delegation of separation assurance, station keeping and other ATC data link messages
4. ERA/A shall automatically inform the ground based ATC system of operation in a degraded mode

3.5.2.6 Operations and Maintenance

1. The ERA/A system shall monitor the inputs received from the navigational source as well as to determine the integrity/reasonableness of the aircraft state and data link messages received.
2. The ERA/A system shall monitor its own operational status and shall automatically report any malfunctions to the ATC system.

3.5.3 ERA/A Functional Design

This section presents the functional design for the ERA/A system that will satisfy the requirements and provide the capabilities previously described. Figure 3.5.3-1 represents the data flow for the ERA/A system.

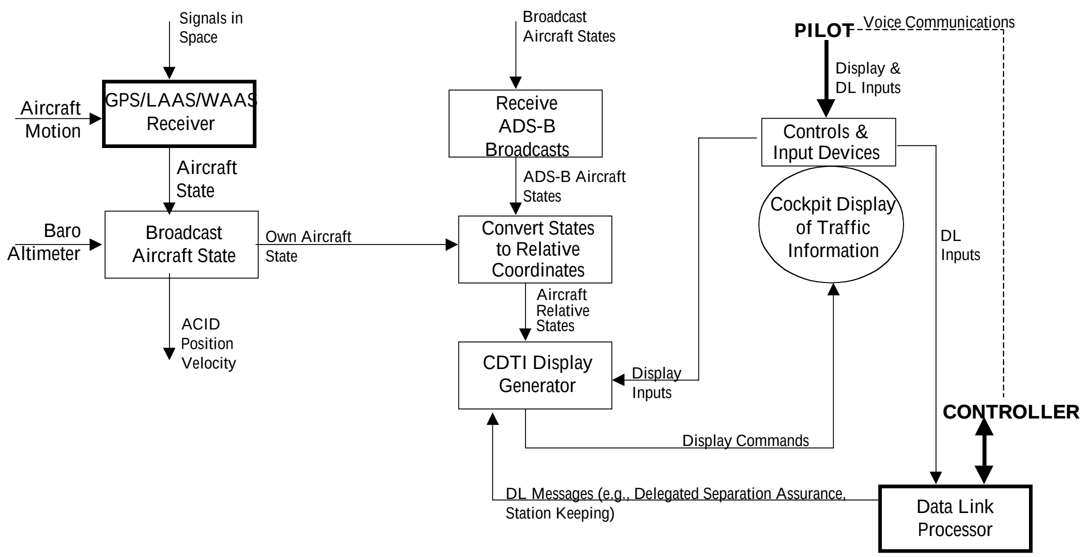


Figure 3.5.3-1 ERA/A Functional Block Diagram

3.5.3.1 System Functional Relationships

The ERA/A system concept will allow the delegation of separation authority to the cockpit resulting in increased efficiency. The ERA/A operates in broadcast mode, interfacing with the satellite signals and corresponding aircraft. The aircraft's computer system receives the coordinates of its own navigational position as well as the navigational position of other aircraft and converts these states to a common reference system relative to own aircraft. The aircraft relative states are forwarded to the CDTI display generator, which outputs the display commands to the CDTI. The CDTI display generator also receives messages from the data link processor unit. The data link processor unit provides data link messages corresponding to delegated separation assurance and station keeping in the en-route domain. The pilot also interfaces with the CDTI via the controls and input devices.

3.5.3.2 Interface Requirements

ERA/A is designed to enhance the situational awareness of the pilot with respect to other aircraft. ERA/A interfaces with the GPS/WAAS satellite constellation to determine its navigational position. The determination of the aircraft state from the satellite constellation and the reception of broadcast messages from other aircraft provide an input to the ERA/A processor. The ERA/A processor interfaces internally with the display generation to provide display commands to the pilot graphical display. The ERA/A processor develops a picture of the surrounding aircraft traffic for the pilot to improve the situational awareness.

3.5.3.2.1 Internal Interfaces

Internal interfaces include:

- Pilot to Display- On/Off Control, Display Select Mode
- GPS Receiver to ERA/A Processor -aircraft position
- Data Link Processor to Display Generator - Relative positions
- Display Generator to Display - Display commands to generate the appropriate ERA/A display

3.5.3.2.2 External Interfaces

External interfaces include:

- GPS Satellite Constellation & GPS Receiver-one way interface to obtain estimate of aircraft state
- Aircraft Transceiver and other aircraft transceivers-two way interface to send/receive aircraft position

3.5.3.3 Human Factors Considerations

The human factor considerations for ERA/A primarily revolve around the design of the ERA/A display and the graphical depiction of the location of nearby traffic. This may be complicated by the need to use a multifunction display that will accommodate the display requirements of many of the other free flight operational enhancements. In addition, pilot interface with the display must include appropriate controls such as zoom, brightness, and contrast, alert off control, display on/off controls, and display mode controls. If using a multifunction display, care must be taken to include features such that if an alert comes from a mode not presently being displayed, it will still be made known to the pilot. The human factor design of this multifunction display must consider the low-end general aviation user.

3.5.3.4 ERA/A Requirements Traceability Matrices

Three aspects of requirement traceability are provided in this section. The first provides traceability between the ERA/A capabilities and the operational requirements as stated in the ATS 2005 CONOPS Narrative and the Joint Government/Industry Operational Concept. The second provides the functional allocation of the operational requirements derived from the ATS 2005 Narrative to the major ATC functions (i.e., communications, navigation, surveillance, weather, automation, maintenance and operations). The third aspect provides recommended requirements validation methodology for each of the functional requirements identified in Section 3.5.2.

3.5.3.4.1 Capabilities to CONOPS Traceability

These operational requirements are derived from the ATS 2005 CONOPS Narrative. They have been developed based upon key word searches of the ATS 2005 Operational Needs database. The key words used in these searches were based on the ERA/A capability descriptions obtained from the RTCA roadmap. Each ERA/A operational requirement is related to at least one ERA/A capability. Table 3.5.3.4.1 provides traceability between the ERA/A capabilities and the operational requirements. In addition, the cross reference of Government/Industry Operational Concept for the Evolution of Free Flight provided as Appendix B of the Joint Government/Industry Roadmap for Free Flight Operational Enhancements was used to provide traceability between the ERA/A capabilities and the RTCA requirements. This mapping is also provided as a column in Table 3.5.3.4.1.

3.5.3.4.2 Operational to Functional Requirement Traceability

Table 3.5.3.4.2 provides the functional allocation of the set of ERA/A operational requirements derived from the ATS 2005 CONOPS Narrative. It must be noted that the requirements obtained in this manner are not all directly related to the ERA/A since they apply to the broader NAS. They are included however for completeness since they result from the searches associated with each ERA/A capability are part of the basis for the derived functional requirements presented in Section 3.5.2.

3.5.3.4.3 Procedures for Functional Requirement Verification

Table 3.5.3.4.3 provides the list of ERA/A functional requirements presented in Section 3.5.2 and the minimum test procedures to verify compliance with those functional requirements. These test procedures include the following test methods: inspection; analysis/simulation; laboratory tests; demonstrations; and, field/flight tests. For certain requirements more than one method may be indicated. Definitions of each of these verification methods are included below.

Table 3.5.3.4-1 ERA/A Capabilities and Requirements

	OPERATIONAL ENHANCEMENT Operational Capabilities	Key Words	Level 1 Narrative Operational Requirement	Joint Industry/Government CONOPS Capabilities Appendix B
5	**Enhanced Operations for En Route Air-to-Air**			**B5**
5.1	Use air-to-air ADS-B position reports for station-keeping and self separation by ADS-B aircraft.	Station,	4.45, 6.26	
		Display,	1.9, 4.12, 4.24, 6.23,	
		Separation	4.12, 4.22, 4.23, 6.22	4.3.1, 5.1.1, 5.3.1, ,6.1.1, 6.2.1, 6.3.1
5.2	Use ADS-B and CDTI to enhance safety in radar and non-radar airspace by assisting the pilot in maintaining situational awareness and visually acquiring proximate traffic and enhancing visual separation.	Awareness,	4.12, 6.23	4.3.1, 5.1.1, 5.3.1
		Satellite,	4.12, 5.7, 5.14, 5.41, 6.6, 6.24	
		Display	1.9, 4.12, 4.24, 6.23,	4.1.1
5.3	Use ADS-B air-to-air and CDTI to support limited station-keeping maneuvers.	Station,	4.45, 6.26	4.3.1, 5.1.1, 5.3.1, 6.1.1
		Display	1.9, 4.12, 4.24, 6.23,	
5.4	Service providers temporarily delegate separation assurance to pilots for properly equipped aircraft pairs of crossing aircraft. ADS-B/CDTI self-separation.	Separation	4.12, 4.22, 6.22	4.3.1, 5.1.1, 5.3.1, 6.2.1, 6.3.1

Table 3.5.3.4-2 ER/A Functional Allocation of Operational Requirements

Level I #	ATS 2005 Statement (Level I Need)	C	N	S	W	A	M
1.9	Replacement of Host … transition to satellite navigation …new display platforms!!Key Words: host navigation display		N			A	
4.12	Satellite-based position data, broadcast by properly equipped aircraft, are used in cockpit traffic displays to increase the pilots' situation awareness for aircraft-to-aircraft separation. These avionics allow an increasingly frequent transfer of responsibility for separation assurance to the flight deck for some types of operations.!!Key Words: self separation!!	C	N	S		A	
4.22	Aircraft-to-aircraft separation remains the responsibility of service providers … in most traffic situations, it remains solely their responsibility.	C		S		A	
4.24	The increased use of this shared responsibility is made feasible through traffic displays on the flight deck, and rules, procedures, and training programs that have modified the roles and responsibilities of users and service providers.					A	M
4.45	On final approach, the service provider may give the pilot responsibility for station keeping to maintain the required sequence and spacing to the runway.	C	N	S		A	
5.7	Surveillance of all positively controlled aircraft is provided by a combination of primary and secondary radar, and the broadcast of satellite-derived position information by individual flights.!!Key Words: surveillance	C		S		A	
5.14	An increasing number of aircraft are equipped with satellite based navigation, digital communications, and the capability to automatically transmit position data.	C	N	S		A	
5.41	For VFR aircraft automatically reporting their satellite-derived positions … coupled with access to the flight's data via the NAS-wide information system, reduces the workload associated with providing traffic advisories to uncontrolled aircraft.!!Key Words: traffic advisories	C	N	S		A	M
6.6	Satellite navigation systems and datalink allow more accurate and frequent traffic position updates; datalink and expanded radio coverage provide direct air-to-ground communications (both digital and voice).!!Key Words: navigation	C	N	S		A	
6.22	The oceanic environment creates opportunity for the transfer of separation assurance to the pilot for specific operations.	C		S		A	
6.23	Pilots have situation awareness of nearby traffic through a cockpit display of traffic information.!!Key Words: CDTI	C		S		A	
6.24	Aircraft position updates are supplied by the aircraft's broadcast of satellite navigation-derived position data transmissions.!!Key Words: position reports	C	N	S		A	

6.26	pilots may obtain approval for special maneuvers such as station keeping with reduced spacing.!!Key Words: stationkeeping	C	N	S		A		

Table 3.5.3.4-3 ERA/A Functional Requirements Verification Definition

tsInsp	Inspection	Verification is based the determination that the system specification includes the requirement, the system was developed to include the capabilities of the requirement, and an examination of the system shows that the capabilities to meet the requirement were included. Results show that the required capability is in the system to the extent verifiable by inspection only.
A/S	Analysis / Simulation	Verification is based on analysis of the developed system capability. This analysis includes desk checking of characteristics and simulation. Operation of the system is not required. Results show that the specified capability, to the extent possible using analysis and simulation, was developed in the system in such a way the required capability is achievable.
Lab	Laboratory Test	Verification is based on operation of the system (in part or as a whole) in a laboratory environment. Some laboratory equipment may be used in place of operational equipment. Results show that specific required capabilities are achievable using the developed system (in part or as a whole) with laboratory instruments used for measurement and stimulation.
Demo	Demonstration Test	Verification is based on operation of the system (in part or as a whole) using operational equipment. Laboratory equipment is not used. Results show that the selected capability is observed using system components.
Field	Field Test	Verification is based on operation of the system using operational equipment in an operational environment. Results show that the selected capability is repeatedly demonstrable in an operational environment
Validation	Validation Test	Verification is based on operation of the system using operational equipment in an operational environment. Results of the comprehensive evaluation of thorough performance testing show that the full scope of the capability is achieved and is repeatable.

Table 3.5.3.4-4 ERA/A Functional Requirement and Verification Procedures

5C-1	The ERA/A shall receive own aircraft position and velocity from GPS which may be augmented with LAAS and/or WAAS and shall broadcast ACID, Position, and velocity in the standardized ADS-B formats.			**X**	**X**	**X**
5C-2	The ERA/A shall receive the ADS-B states of other aircraft.				**X**	**X**
5C-3	The ERA/A shall receive delegated separation assurance, station keeping and other messages from the ATC automation system via data link and shall distribute these messages to the ERA/A display generator.			**X**	**X**	**X**
5C-4	Voice communications shall be available between the pilot and the controller however this is not considered an ERA/A functional requirement.	**X**			**X**	
5C-5	The ERA/A shall communicate operation in a degraded navigational mode to the ground based ATC system when this situation occurs.		**X**	**X**		
5N-1	The ERAA system shall receive its navigational position from GPS, when available.				**X**	**X**
5N-2	The navigational position information shall be able to accommodate WAAS and LAAS satellite information, when available.			**X**		
5N-3	If GPS is not available, the aircraft shall use an appropriate area navigation instrument to provide an input to the ERAA processor.			**X**	**X**	
5A-1	ERA/A shall automatically convert all ADS-B aircraft states into own aircraft relative coordinates.		**X**	**X**	**X**	**X**
5A-2	ERA/A shall automatically process all display inputs from the pilot. These inputs shall at a minimum include control of display brightness, contrast, location of own aircraft on the display, and on/off controls.	**X**		**X**	**X**	
5A-3	ERA/A shall automatically process and display delegation of separation assurance, station keeping and other ATC data link messages.			**X**		
5A-4	ERA/A shall automatically inform the ground based ATC system of operation in a degraded mode.		**X**	**X**		
5OM-1	The ERA/A system shall monitor the inputs received from the navigational source as well as to determine the integrity/reasonableness of the aircraft state and data link messages received.			**X**		
5OM-2	The ERA/A system shall monitor its own operational status and shall automatically report any malfunctions to the ATC system.			**X**		

3.6 Surface/Approach Operations (S/AO) Functional Specification

This functional specification for the S/AO consists of a detailed description of the S/AO system concept, a presentation of the S/AO functional requirements for each of the major ATC functions (i.e., Communications, Navigation, Surveillance, Weather, Automation, and Maintenance and Operations), and an elaboration of the S/AO functional design including functional flow diagrams and interface requirements.

3.6.1 S/AO System Concept

The S/AO concept consists of a definition of the operational concept, the capabilities, and the expected benefits. Within the operational concept, the S/AO mission and modes of operation are also defined. Figure 3.6.1-1 illustrates the S/AO concept and shows that it consists primarily of data collection, processing, and display functions. In essence, information that will enhance a pilot's awareness of the presence of other aircraft and surface vehicles is broadcast to pilots using the Automatic Dependent Surveillance-Broadcast (ADS-B) system. S/AO does not directly perform surveillance of aircraft but rather uses the information made available from the air-to-air mode of ADS-B. In addition, S/AO provides approach and departure guidance to pilots based on the GPS/LAAS Approach and Landing system. Finally, Terminal Radar Procedures (TERPS) for the GPS/LAAS Approach and Landing system are developed to support the S/AO concept.

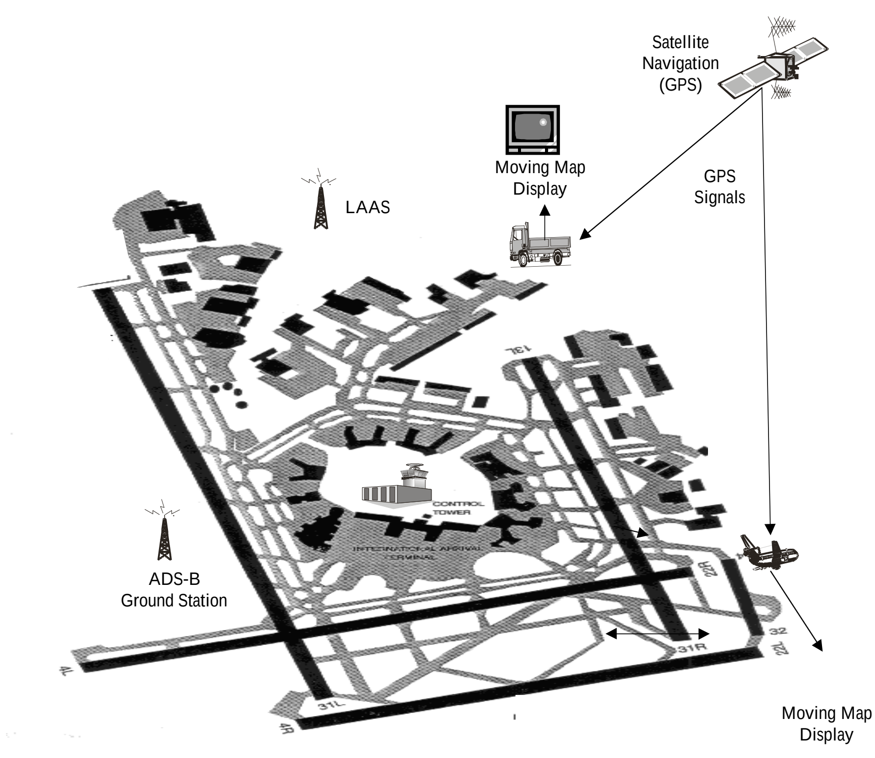


Figure 3.6.1-1: S/AO System Concept

3.6.1.1 S/AO Operational Concept

Improved Surface /Approach Operations provides information needed by pilots to operate more safely and efficiently during the approach, landing, and taxi phases of flight. The pilots in the cockpit and the operators of equipped vehicles on the airport surface would be able to "see" all the other traffic on a display with a moving map, resulting in safer and more efficient surface operations. Also, aircraft will be able to taxi using augmented GPS navigation and maps in extremely low visibility conditions using LAAS. LAAS precision approaches and missed approaches will be installed at sites with surface navigation and traffic monitoring. Next generation equipment and procedures (including TERPS) to permit the design and implementation of LAAS precision approaches and precision departures/missed approaches to all runway ends will be developed to support S/AO. Thus, S/AO will provide reduction in runway incursion incidents, reduction in taxi delays, and will increase the predictability of taxi times.

3.6.1.1.1 Mission

Many times, especially in low visibility, it is difficult for pilots to navigate the taxiways of the airport. If the pilot is not familiar with the airport, clearances may not be properly executed with the resulting safety implications. Furthermore, under reduced visibility conditions the pilot may not be able to see other traffic. Enhanced traffic situational awareness will improve the safety and efficiency of surface operations. Thus, the mission of the S/AO system can be stated as:

Improve flight safety and efficiency through increased situational awareness of surface traffic and airport configuration especially during low visibility conditions.

3.6.1.1.2 Modes of Operation

The principle mode of S/AO operation is the surface mode. In this mode, ADS-B is used to broadcast the positions of all surface traffic including aircraft and vehicles. This information is correlated with airport map data and presented to the pilot on a moving map display Taxi clearances are communicated to the pilot using voice communications and/or datalink. Datalink clearances are displayed on the moving map display. A secondary mode of operation is during approach or departure when the flight is below 1000 feet. In this mode the operation is similar to the principle mode with the exception that aircraft altitude is used as part of the aircraft state rather than an on-surface indication. This secondary mode is important to S/AO since it will reduce the potential for runway incursions and associated incidents.

3.6.1.2 S/AO Capabilities

The implementation of S/AO provides the following operational capabilities:

- Pilots use a cockpit display of the airport surface (moving map display) with the location of their own aircraft and other traffic indicated.
- LAAS precision approaches and missed approaches are to be installed at sites with surface navigation and traffic monitoring. This capability is not to slow down development of the S/AO Surface Mode.

- Next generation equipment and procedures (including new TERPS) to permit the design and implementation of LAAS precision approaches and missed approaches to all runway ends is to be installed at sites with surface navigation and traffic monitoring. This capability is not to slow down development of the S/AO Surface Mode.

3.6.1.3 S/AO Benefits

The improved S/AO is expected to produce the following benefits:

- Reduction in runway incursion incidents
- Reduction in taxi delays
- Increased predictability of taxi times
- Improved approach/missed approach operations and procedures
- Increased airport capacity and reduced delays during low visibility conditions

3.6.2 S/AO Functional Requirements

The functional requirements for S/AO have been developed by first considering the S/AO capabilities and then determining the relevant operational needs as stated in the ATS 2005 CONOPS Narrative. The operational capabilities and needs were then analyzed to determine the ATC functions, which were required to satisfy the need. These S/AO operational requirements are presented as requirements traceability matrices in Section 3.6.3.4 and are summarized for each of the major ATC functions in the following paragraphs.

3.6.2.1 Communications

The communications requirements for S/AO are primarily associated with transmitting and receiving ADS-B broadcasts of aircraft state and airport surface vehicles. In addition, data link and voice communications with the ground-based system are assumed. The S/AO enhancement is expected to process all S/AO related data link messages from the ground based ATC system including alert messages and ATC clearances. An analysis of the detailed communications requirements contained in the requirements traceability matrix (Section 3.6.3.4) coupled with an examination of the required capabilities results in the following set of communications functional requirements:

1. The S/AO shall receive own aircraft position and velocity from GPS which must be augmented with LAAS and shall broadcast ACID, position, and velocity in the standardized ADS-B formats
2. The S/AO shall receive the ADS-B states of other aircraft and surface vehicles
3. The S/AO shall ATC clearances, alerts and other messages from the ATC automation system via data link and shall distribute these messages to the S/AO moving map display generator.
4. Voice communications shall be available between the pilot and the controller however this is not considered an S/AO functional requirement
5. The S/AO shall communicate operation in a degraded navigational mode to the ground based ATC system when this situation occurs.

3.6.2.2 Navigation

The S/AO requires precise navigational information that uses satellite information augmented with LAAS to derive position. An analysis of the detailed navigational requirements contained in the requirement traceability matrix results in the following set of navigational functional requirements:

1. The S/AO system shall receive its navigational position from GPS/LAAS when available.
2. The navigational position information shall be able to receive WAAS satellite information, when available.
3. If GPS/LAAS is not available, the aircraft shall use an appropriate area navigation instrument to provide an input to the S/AO processor.

3.6.2.3 Surveillance

S/AO has no direct ATC surveillance requirements although it is assumed that the aircraft is under ATC surveillance and control. S/AO does however depend upon ADS-B surveillance capability. An analysis of the detailed surveillance requirements contained in the requirement traceability matrix (Section 3.6.3.4) coupled with an examination of the required S/AO capabilities results in the following set of airborne surveillance functional requirements:

1. S/AO shall receive ADS-B aircraft and airport surface vehicle states from the ADS-B air-to-air broadcasts of aircraft state and the broadcasts of surface vehicle states.
2. S/AO shall broadcast its own aircraft state for use by the ground ATC surveillance system and for surface surveillance by other properly equipped aircraft.

3.6.2.4 Weather

S/AO does not have any directly related functional requirements in the weather area

3.6.2.5 Automation

The automation functions required by S/AO involve: processing of ADS-B aircraft and surface vehicle state information; processing of airport map data; the development of appropriate commands to drive the moving map display; and, processing and display of data link messages including ATC clearances and alerts transmitted by the ground based ATC automation system or by controller input. ATC automation is not considered part of the S/AO system but it is recognized that it must provide inputs to the S/AO using the data link. Analysis of the detailed automation requirements contained in the requirement traceability matrix (Section 3.6.3.4) coupled with an examination of the required S/AO capabilities results in the following set of airborne automation functional requirements:

1. S/AO shall automatically convert all ADS-B aircraft and surface vehicle states into airport map coordinates
2. S/AO shall automatically convert all aircraft and surface vehicle states and airport maps into own aircraft coordinates
3. S/AO shall automatically process all display inputs from the pilot. These inputs shall at a minimum include control of display brightness, contrast, location of own aircraft on the display, and on/off controls.

4. S/AO shall automatically process and display ATC clearances and alerts
5. S/AO shall display all airport traffic relative to own aircraft on a display of an airport map that is centered on own aircraft and that moves with the aircraft.
6. S/AO shall automatically inform the ground based ATC system of operation in a degraded mode

3.6.2.6 Operations and Maintenance

1. The S/AO system shall monitor the inputs received from the navigational source as well as to determine the integrity/reasonableness of the aircraft and surface vehicle states and data link messages received.
2. The S/AO system shall monitor its own operational status and shall automatically report any malfunctions to the ATC system.

3.6.3 S/AO Functional Design

This Section presents the functional design for the S/AO that will satisfy the requirements and provide the capabilities previously described. In addition, the S/AO data flow will also be discussed as part of the overall functional design. To begin, consider the functional flow chart for the S/AO functional design presented as Figure 3.6.3-1.

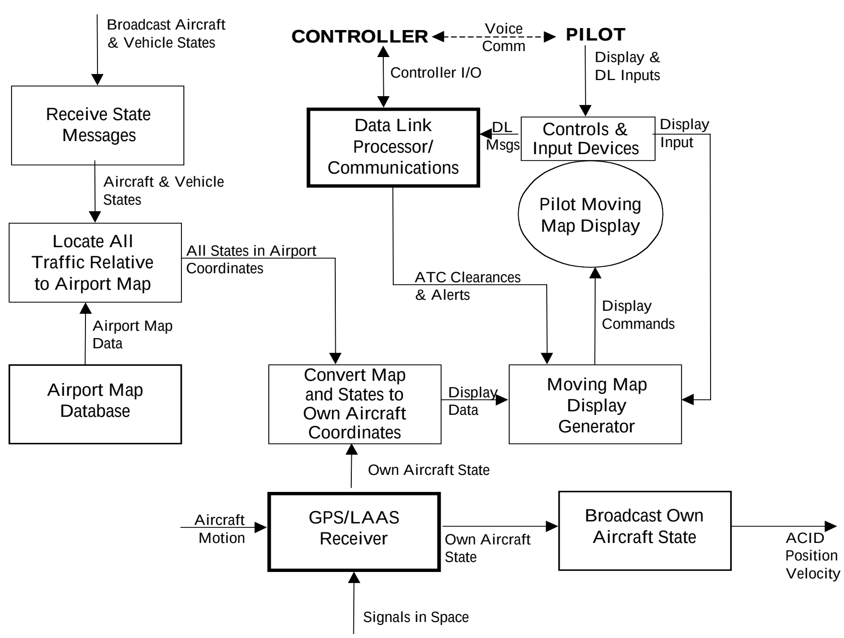


Figure 3.6.3-1 S/AO Functional Block Diagram

3.6.3.1 System Functional Relationships

S/AO has two modes of operation: surface mode; and, approach/departure mode. These modes are identical in operation with the exception that the approach/departure mode operates under 1000 feet and uses the actual altitude of the aircraft as an element of the aircraft state. In the surface mode, a surface indication is used in place of altitude. With this difference noted, it suffices to discuss the functional design and relationships for both modes simultaneously.

SOA operation begins with the reception of own aircraft position from the GPS/LAAS Receiver. Altitude is also obtained from the LAAS and from a barometric altimeter, but if the aircraft is on the ground, an on-surface altitude code is used. Own aircraft state is used as the input to two functions. The first is to broadcast own aircraft state including identity on the common frequency used for ADS-B purposes. This allows other suitably equipped aircraft and vehicles to receive the state of the subject aircraft so that it can be included in their S/AO capability. The second use of own aircraft state is to establish an aircraft centered coordinate system, which can be used to convert all aircraft and vehicle traffic, and airport maps to own aircraft centered coordinates. This will then permit the aircraft map and other traffic to be displayed relative to own aircraft and to be shown moving with own aircraft motion.

As mentioned above, the S/AO enhancement must receive the states of all surface traffic and traffic below 1000 feet. This information is obtained from the ADS-B broadcasts of all aircraft and surface vehicles. In addition, the specific airport map data is obtained from an on-board airport map database that could be stored on a CD or some other suitable storage medium. It is important for S/AO to have the most recent airport mapping information.

Given the airport map information and the states of other aircraft and surface vehicles, it is possible to convert all of this information to a set of own aircraft coordinates using the knowledge of own aircraft state. This information of own aircraft position relative to the airport map and to other aircraft and vehicles is then passed to the display generator that develops the commands needed to drive the pilot display. The display generator also processes data link messages including ATC clearances and alerts; and it processes the display inputs generated by the pilot. Clearances may include taxi/gate instructions or arrival/departure instructions; alerts may include warning of runway incursion or proximate aircraft or surface vehicles; pilot display inputs may include zoom, location of own aircraft on the display, brightness and contrast, alert off control, and display on/off controls.

3.6.3.2 Interface Requirements

Examining the S/AO functional design illustrated in Figure 3.6.3-1 one observes that there are four major inputs to the S/AO. The first is own aircraft state from the GPS/LAAS Receiver. The second is the airport map information from the airport map database, and the third is the ADS-B broadcast information from other aircraft and surface vehicles. The fourth interface is with the data link processor and communications system used for transmission of data link ATC clearances and alerts. Several interfaces also exist within the S/AO enhancement among the S/AO functional elements. Both the internal and external S/AO interfaces are identified in the following paragraphs.

3.6.3.2.1 Internal Interfaces

Internal interfaces include:

- Pilot/Display - all pilot initiated display controls
- S/AO Processor/Display - compatible message format and display driver commands
- S/AO Processor/Airport Map Database - specific airport map characteristics including runways, taxiways, and gate locations

3.6.3.2.2 External Interfaces

External interfaces include S/AO interfaces with:

- Data Link Processor/Communications System - two way interface for data link message transmission and reception
- GPS/LAAS Receiver - one way interface to obtain own aircraft state from the GPS/LAAS system
- ADS-B Interface - for the reception of ADS-B broadcasts from other aircraft and surface vehicles and for the broadcast of own aircraft state.

3.6.3.3 Human Factors Considerations

The human factor considerations for S/AO primarily revolve around the design of the S/AO moving map display and the graphical depiction of the location of traffic of interest and airport map information relative to own aircraft. This may be complicated by the need to use a multifunction display that will accommodate the display requirements of many of the other free flight operational enhancements. In addition, pilot interface with the display must include appropriate controls such as zoom, brightness, and contrast, alert off control, display on/off controls, and display mode controls. If using a multifunction display, care must be taken to include features such that if an alert comes from a mode not presently being displayed, it will still be made known to the pilot. The human factor design of this multifunction display must consider the low-end general aviation user.

3.6.3.4 S/AO Requirements Traceability Matrices

Three aspects of requirement traceability are provided in this section. The first provides traceability between the S/AO capabilities and the operational requirements as stated in the ATS 2005 CONOPS Narrative and the Joint Government/Industry Operational Concept. The second provides the functional allocation of the operational requirements derived from the ATS 2005 Narrative to the major ATC functions (i.e., communications, navigation, surveillance, weather, automation, maintenance and operations). The third aspect provides recommended requirements validation methodology for each of the functional requirements identified in Section 3.6.2.

3.6.3.4.1 Capabilities to CONOPS Traceability

These operational requirements are derived from the ATS 2005 CONOPS Narrative. They have been developed based upon key word searches of the ATS 2005 Operational Needs database.

The key words used in these searches were based on the S/AO capability descriptions obtained from the RTCA roadmap. Each S/AO operational requirement is related to at least one S/AO capability. Table 3.6.3.4.- provides traceability between the S/AO capabilities and the operational requirements. In addition, the cross reference of Government/Industry Operational Concept for the Evolution of Free Flight provided as Appendix B of the Joint Government/Industry Roadmap for Free Flight Operational Enhancements was used to provide traceability between the S/AO capabilities and the RTCA requirements. This mapping is also provided as a column in Table 3.6.3.4-1.

3.6.3.4.2 Operational to Functional Requirement Traceability

Table 3.6.3.4-2 provides the functional allocation of the set of S/AO operational requirements derived from the ATS 2005 CONOPS Narrative. It must be noted that the requirements obtained in this manner are not all directly related to the S/AO since they apply to the broader NAS. They are included however for completeness since they result from the searches associated with each S/AO capability are part of the basis for the derived functional requirements presented in Section 3.6.2.

3.6.3.4.3 Procedures for Functional Requirement Verification

Table 3.6.3.4-3 provides the list of S/AO functional requirements presented in Section 3.6.2 and the minimum test procedures to verify compliance with those functional requirements. These test procedures include the following test methods: inspection; analysis/simulation; laboratory tests; demonstrations; and, field/flight tests. For certain requirements more than one method may be indicated. Definitions of each of these verification methods are provided below.

Table 3.6.3.4-1 S/AO Capabilities and Requirements

	OPERATIONAL ENHANCEMENT Operational Capabilities	Key Words	Level 1 Narrative Operational Requirement	Joint Industry/Government CONOPS Capabilities Appendix B
6	**Improved Surface/Approach Operations**			**B6**
6.1	Pilots use a cockpit display of the airport surface (moving map display) with the location of their own aircraft and other traffic indicated.	Display, Map	1.9, 4.12, 4.24, 6.23 No Hits	3.1, 3.1.2, 3.2, 3.3, 3.3.1 3.1, 3.1.2, 3.2, 3.3, 3.3.1
6.2	LAAS precision approaches and missed approaches - Not to slow down development. To be installed at sites with surface navigation and traffic monitoring.	Augmentation	3.29, 4.63	3.3
6.3	Next generation equipment and procedures (including new TERPS) to permit the design and implementation of LAAS precision approaches and precision missed approaches to all runway ends. Not to slow down development. To be installed at sites with surface navigation and traffic monitoring.	Augmentation, TERPS, Procedures	3.29, 4.63 No Hits 1.7, 1.35, 4.24	3.3

Table 3.6.3.4-2 S/AO Functional Allocation of Operational Requirements

Level I #	ATS 2005 Statement (Level I Need)	C	N	S	W	A	M	comments (to be del
1.7	The air traffic system must evolve in the areas of airspace and procedures, roles and responsibilities, equipment, and automation. !Key Words: (or) airspace procedures roles responsibilities equipment automation	C	N	S	W	A		
1.9	Replacement of Host … transition to satellite navigation …new display platforms!!Key Words: host navigation display		N			A		
1.35	Procedural changes are developed, evaluated, and instituted to meet technology as it arrives, rather than post-deployment. !!Key Words: procedures	C	N	S	W	A	M	
3.29	Visual cues that service providers currently rely upon are augmented with enhanced situation displays and surface detection equipment.!!Key Words: separation			S		A		
4.12	Satellite-based position data, broadcast by properly equipped aircraft, are used in cockpit traffic displays to increase the pilots' situation awareness for aircraft-to-aircraft separation. These avionics allow an increasingly frequent transfer of responsibility for separation assurance to the flight deck for some types of operations.!!Key Words: self separation!!	C	N	S		A		
4.24	The increased use of this shared responsibility is made feasible through traffic displays on the flight deck, and rules, procedures, and training programs that have modified the roles and responsibilities of users and service providers.					A	M	
4.63	Augmentation systems have the accuracy, availability, integrity, and continuity necessary for precision approaches. Separation standards are set in accordance to the accuracy of the positional information.!!Key Words: precision approach		N			A	M	
6.23	Pilots have situation awareness of nearby traffic through a cockpit display of traffic information.!!Key Words: CDTI	C		S		A		CONOP applicabl comes from oce chapter - may use (dis

Table 3.6.3.4-3 S/AO Functional Requirement Verification Definition

Insp	Inspection	Verification is based the determination that the system specification includes the requirement, the system was developed to include the capabilities of the requirement, and an examination of the system shows that the capabilities to meet the requirement were included. Results show that the required capability is in the system to the extent verifiable by inspection only.
A/S	Analysis / Simulation	Verification is based on analysis of the developed system capability. This analysis includes desk checking of characteristics and simulation. Operation of the system is not required. Results show that the specified capability, to the extent possible using analysis and simulation, was developed in the system in such a way the required capability is achievable.
Lab	Laboratory Test	Verification is based on operation of the system (in part or as a whole) in a laboratory environment. Some laboratory equipment may be used in place of operational equipment. Results show that specific required capabilities are achievable using the developed system (in part or as a whole) with laboratory instruments used for measurement and stimulation.
Demo	Demonstration Test	Verification is based on operation of the system (in part or as a whole) using operational equipment. Laboratory equipment is not used. Results show that the selected capability is observed using system components.
Field	Field Test	Verification is based on operation of the system using operational equipment in an operational environment. Results show that the selected capability is repeatedly demonstrable in an operational environment
Validation	Validation Test	Verification is based on operation of the system using operational equipment in an operational environment. Results of the comprehensive evaluation of thorough performance testing show that the full scope of the capability is achieved and is repeatable.

Table 3.6.3.4-4 S/AO Functional Requirement and Verification Procedures

Number	Functional Requirement	Insp	A/S	Lab	Demo	Field
6C-1	The SAO shall receive own aircraft position and velocity from GPS which must be augmented with LAAS and shall broadcast ACID, position, and velocity in the standardized ADS-B formats.			X	X	X
6C-2	The SAO shall ATC clearances, alerts and other messages from the ATC automation system via data link and shall distribute these messages to the SAO moving map display generator.				X	
6C-3	The SAO shall receive the ADS-B states of other aircraft and surface vehicles.				X	X
6C-4	Voice communications shall be available between the pilot and the controller however this is not considered an SAO functional requirement.	X			X	
6C-5	The SAO shall communicate operation in a degraded navigational mode to the ground based ATC system when this situation occurs.		X	X		
6N-1	The SAO system shall receive its navigational position from GPS/LAAS when available.			X	X	
6N-2	The navigational position information shall be able to receive WAAS satellite information, when available.			X		
6N-3	If GPS/LAAS is not available, the aircraft shall use an appropriate area navigation instrument to provide an input to the SAO processor.			X	X	
6S-1	SAO shall receive ADS-B aircraft and airport surface vehicle states from the ADS-B air-to-air broadcasts of aircraft state and the broadcasts of surface vehicle states.			X	X	
6S-2	SAO shall broadcast its own aircraft state for use by the ground ATC surveillance system and for surface surveillance by other properly equipped aircraft.			X		X
6A-1	SAO shall automatically convert all ADS-B aircraft and surface vehicle states into airport map coordinates.		X	X	X	X
6A-2	SAO shall automatically convert all aircraft and surface vehicle states and airport maps into own aircraft coordinates.		X	X		X
6A-3	SAO shall automatically process all display inputs from the pilot. These inputs shall at a minimum include control of display brightness, contrast, location of own aircraft on the display, and on/off controls.	X		X	X	
6A-4	SAO shall automatically process and display ATC clearances and alerts.			X	X	
6A-5	SAO shall display all airport traffic relative to own aircraft on a display of an airport map that is centered on own aircraft and that moves with the aircraft.			X		X
6A-6	SAO shall automatically inform the ground based ATC system of operation in a degraded mode.		X	X		
6OM-1	The SAO system shall monitor the inputs received from the navigational source as well as to determine the integrity/reasonableness of the aircraft and surface vehicle			X		

Number	Functional Requirement	Insp	A/S	Lab	Demo	Field
	states and data link messages received.					

3.7 Airport Surface Display (ASD) Functional Specification

This functional specification for the ASD consists of a detailed description of the ASD system concept, a presentation of the ASD functional requirements for each of the major ATC functions (i.e., Communications, Navigation, Surveillance, Weather, Automation, and Maintenance and Operations), and an elaboration of the ASD functional design including functional flow diagrams and interface requirements.

3.7.1 ASD System Concept

The ASD concept consists of a definition of the operational concept, the capabilities, and the expected benefits. Within the operational concept, the ASD mission and modes of operation are also defined. Figure 3.7.1-1 illustrates the ASD concept and shows that it consists primarily of data collection, processing, and display functions. In essence, information that will enhance a controller's awareness of the identity, position, speed and heading of aircraft and surface vehicles is displayed to controllers using the Automatic Dependent Surveillance-Broadcast (ADS-B) system as input. ASD does not directly perform surveillance of aircraft or surface vehicles but rather uses the information made available from the air-to-ground mode of ADS-B and ASDE where it is available. ASDE is only used to identify non-ADS-B targets or targets with a failed ADS-B at airports where ASDE is available. Display of targets and their tracks relative to an airport map depicting runway, taxiway, and gate locations is envisioned as part of this enhancement. In addition, weather and automatic weather hazard, proximity risk, and runway incursion alerts are also displayed.

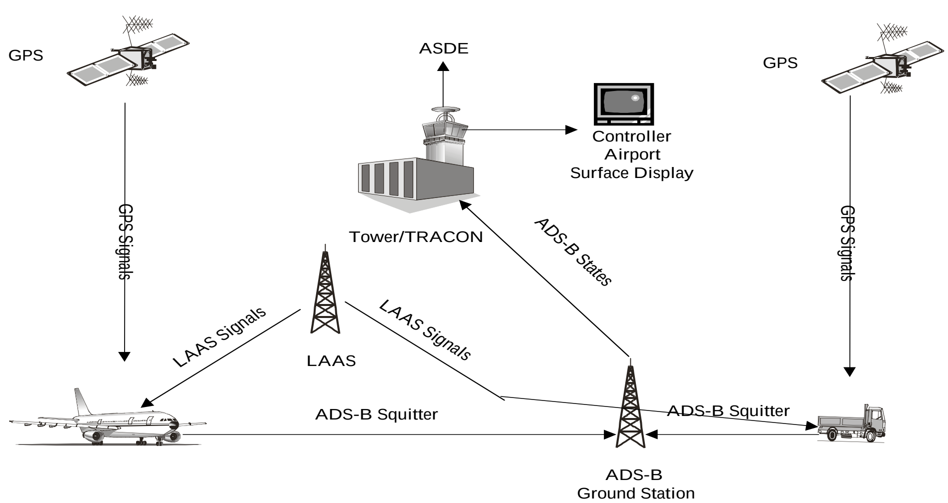


Figure 3.7.1-1: ASD System Concept

3.7.1.1 ASD Operational Concept

Airport Surface Display for the Controller provides information needed by controllers to operate more safely and efficiently during the approach, landing, and taxi phases of flight especially during low visibility conditions. Aircraft and ground vehicles in the airport movement area will be equipped with ADS-B using augmented GPS derived positions. For those locations with ADSE, the ADSE data does not give complete information about the identification, position, speed, and heading of all the traffic on the airport surface. Thus, ADSE will be used only for purposes of detecting non-ADS-B traffic and will reinforce ADS-B targets. With ID, position, speed, and heading of all surface traffic, the local and ground controllers in the tower will be able to monitor the movement of all in the airport movement area traffic relative to the airport configuration. Weather and alerts from ATC automation systems including automatic weather hazard, proximity risk, and runway incursion alerts are also displayed to the controlled on the ASD.

3.7.1.1.1 Mission

Many times, especially in low visibility, it is difficult for tower controllers to manage the aircraft and other vehicle traffic on the airport surface. Enhanced traffic situational awareness for the tower controllers will improve the safety and efficiency of surface operations. Thus, the mission of the ASD system can be stated as:

Improve flight safety and efficiency through increased situational awareness of airport surface traffic especially during low visibility conditions.

3.7.1.1.2 Modes of Operation

The ASD mode of operation is the surface mode. In this mode, ADS-B is used to display the positions of all surface traffic including aircraft and vehicles. This information is correlated with airport map data and presented to the tower controllers. In addition, ATC automation alerts and weather information is also provided for display to the controllers on the ASD.

3.7.1.2 ASD Capabilities

The implementation of ASD provides the following operational capabilities:

- Service providers use a surface situation display that depicts the airport surface and nearby airspace.
- All aircraft and surface vehicles are displayed with data tags (i.e., ID, type, heading, speed) and GPS derived positions

3.7.1.3 ASD Benefits

The improved ASD is expected to produce the following benefits:

- Reduction in runway incursion incidents
- Reduction in taxi delays
- Increased predictability of taxi times

- Improved approach/missed approach operations and procedures
- Increased airport capacity (arrival and departure rates) and reduced delays during low visibility conditions

3.7.2 ASD Functional Requirements

The functional requirements for ASD have been developed by first considering the ASD capabilities and then determining the relevant operational needs as stated in the ATS 2005 CONOPS Narrative. The operational capabilities and needs were then analyzed to determine the ATC functions, which were required to satisfy the need. These ASD operational requirements are presented as requirements traceability matrices in Section 3.7.3.4 and are summarized for each of the major ATC functions in the following paragraphs.

3.7.2.1 Communications

The communications requirements for ASD are primarily internal to the ATC automation system. No external communications requirements are necessary for the ASD operational enhancement.

3.7.2.2 Navigation

There are no navigation functional requirements associated with the ASD operational enhancement.

3.7.2.3 Surveillance

ASD depends upon interfacing with the ATC surveillance track file that contains the identity, position, and velocity of all aircraft and surface vehicles in the airport area below 1000 feet. An analysis of the detailed surveillance requirements contained in the requirement traceability matrix (Section 3.7.3.3) coupled with an examination of the required ASD capabilities results in the following set of airborne surveillance functional requirements:

1. ASD shall receive ADS-B aircraft and airport surface vehicle tracks from the ATC surveillance system track file.
2. ADSE data shall only be used by the ATC surveillance system to reinforce the ADS-B tracks in the surveillance track file. In the event that an ASDE target exists which does not have a corresponding ASD-B track, it shall be included in the track file as "unidentified" and processed as a surface vehicle target.

3.7.2.4 Weather

ASD does not have any directly related functional requirements in the weather area although it is expected that local weather will be displayed on the ASD.

3.7.2.5 Automation

The automation functions required by ASD involve processing of ADS-B aircraft and surface vehicle state information; processing of airport map data; and, the development of appropriate commands to drive the ASD. ATC automation is not considered part of the ASD system but it is recognized that it must provide surveillance track inputs to the ASD. Analysis of the detailed automation requirements contained in the requirement traceability matrix (Section 3.7.3.3) coupled with an examination of the required ASD capabilities results in the following set of automation functional requirements:

1. ASD shall automatically convert all ADS-B aircraft and surface vehicle states into display coordinates
2. ASD shall automatically convert all "unidentified" ASDE tracks states into display coordinates and shall assume that the track belongs to a surface vehicle.
3. ASD shall automatically convert all airport and local airspace maps into display coordinates
4. ASD shall automatically process all display inputs from the controller. These inputs shall at a minimum include control of display brightness, contrast, zoom, coordinates and on/off controls.
5. ASD shall automatically display the locations, identity, heading, speed, and altitude or on-surface indication for all aircraft below 1000 feet and all airport surface vehicles. In the event of an "unidentified" ASDE target, a special unambiguous tag shall be assigned indicating that the target is "unidentified".
6. ASD shall automatically display all alerts from the ATC automation system to the controller
7. ASD shall automatically display all available local weather from the ATC automation system to the controller. The controller shall have the capability to suppress this weather information at his or her discretion.

3.7.2.6 Operations and Maintenance

1. The ASD system shall monitor the inputs received from data sources to determine the integrity/reasonableness of the aircraft and surface vehicle states and the map data received.
2. The ASD system shall monitor its own operational status and shall automatically report any malfunctions to the ATC Maintenance Monitoring system.

3.7.3 ASD Functional Design

This Section presents the functional design for the ASD that will satisfy the requirements and provide the capabilities previously described. In addition, the ASD data flow will also be discussed as part of the overall functional design. To begin, consider the functional flow chart for the ASD functional design presented as Figure 3.7.3-1.

3.7.3.1 System Functional Relationships

The ASD primary inputs are from the ADS-B Surveillance track file and from the ASDE at airports where ASDE is available. These inputs are processed by an ADS-B to ASDE target correlator that reinforces some of the ADS-B tracks with the ASDE target data. Other ADS-B tracks will not be reinforced and certain ASDE tracks will not have a corresponding ADS-B track. These ASDE targets will be declared an uncorrelated and will be displayed without tags.

These targets will be assumed to be ground vehicles or aircraft without ADS-B capability. Once correlation has been completed, the tracks will be converted to a set of display coordinates defined by the controller and the information will be forwarded to the display generator. Airport and airspace maps will also be converted to the controller selected display coordinates and forwarded to the display generator. In addition, ATC Automation will provide a set of alerts for hazardous weather, traffic proximity risk, and runway incursions. These alerts will similarly be forwarded to the ASD display generator.

The ASD display generator is the heart of the ASD and converts all display information (i.e., aircraft and vehicle states, alerts, weather, airport and airspace maps, and controller display inputs and controls) into a set of display commands that drive the ASD display.

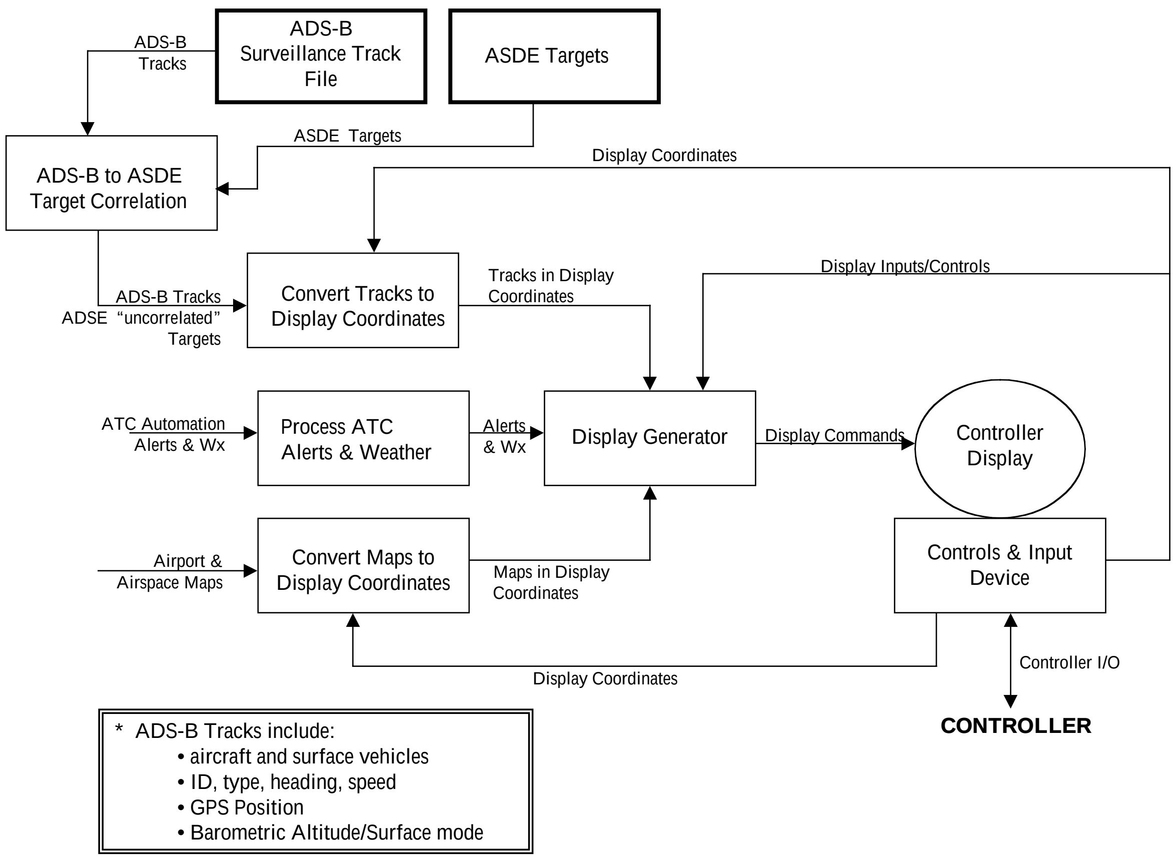


Figure 3.7.3-1 ASD Functional Block Diagram

3.7.3.2 Interface Requirements

Examining the ASD functional design illustrated in Figure 3.7.3-1 one observes that there are four major inputs to the ASD. The first is aircraft and surface vehicle states from the ADS-B Surveillance Track File and the ASDE. The second is the airport map information from the airport map database, and the third is the ATC automation alerts and the weather data. The fourth interface is with the controller who will input display controls such as display coordinates, zoom, brightness and contrast, alert on/off commands and the like. Several interfaces also exist within the ASD enhancement among the ASD functional elements. Both the internal and external ASD interfaces are identified in the following paragraphs.

3.7.3.2.1 Internal Interfaces

Internal interfaces include:

- Controller/Display - all controller initiated display controls
- ASD Processor/Display - compatible message format and display driver commands
- ASD Processor/Airport Map Database - specific airport map characteristics including runways, taxiways, and gate locations

3.7.3.2.2 External Interfaces

External interfaces include ASD interfaces with:

- ADS-B Surveillance Track File to obtain all ADS-B tracks of aircraft and surface vehicles
- ADSE Targets to obtain all primary radar targets for correlation with ADS-B tracks
- ATC Automation for all alerts and weather information
- Airport and Airspace Maps - this may either be internal or external to the ASD depending on the specific system design

3.7.3.3 Human Factors Considerations

The human factor considerations for ASD primarily revolve around the design of the ASD display and the graphical depiction of the location of traffic of interest, alerts, weather, and airport map information. In addition, controller interface with the display must include appropriate controls such as zoom, brightness, and contrast, alert off control, display on/off controls, and display mode controls. The controller will also be expected to input an appropriate set of display coordinates. A major challenge for the ASD is the methodology used for the display of targets. ADS-B target information is asynchronous and does not resemble the traditional radar presentation with a scanning beam. Thus, it may be that the display generator will have to simulate a radar scan in order for this display to be acceptable to the service providers.

3.7.3.4 ASD Requirements Traceability Matrices

Three aspects of requirement traceability are provided in this section. The first provides traceability between the ASD capabilities and the operational requirements as stated in the ATS 2005 CONOPS Narrative and the Joint Government/Industry Operational Concept. The second provides the functional allocation of the operational requirements derived from the ATS 2005 Narrative to the major ATC functions (i.e., communications, navigation, surveillance, weather, automation, maintenance and operations). The third aspect provides a recommended requirement validation methodology for each of the functional requirements identified in Section 3.7.2.

3.7.3.4.1 Capabilities to CONOPS Traceability

These operational requirements are derived from the ATS 2005 CONOPS Narrative. They have been developed based upon key word searches of the ATS 2005 Operational Needs database. The key words used in these searches were based on the ASD capability descriptions obtained from the RTCA roadmap. Each ASD operational requirement is related to at least one ASD capability. Table 3.7.3.4-1 provides traceability between the ASD capabilities and the operational requirements. In addition, the cross reference of Government/Industry Operational Concept for the Evolution of Free Flight provided as Appendix B of the Joint Government/Industry Roadmap for Free Flight Operational Enhancements was used to provide traceability between the ASD capabilities and the RTCA requirements. This mapping is also provided as a column in Table 3.7.3.4-1.

3.7.3.4.2 Operational to Functional Requirement Traceability

Table 3.7.3.4-2 provides the functional allocation of the set of ASD operational requirements derived from the ATS 2005 CONOPS Narrative. It must be noted that the requirements obtained in this manner are not all directly related to the ASD since they apply to the broader NAS. They are included however for completeness since they result from the searches associated with each ASD capability are part of the basis for the derived functional requirements presented in Section 3.7.2.

3.7.3.4.3 Procedures for Functional Requirement Verification

Table 3.7.3.4-3 provides the list of ASD functional requirements presented in Section 3.7.2 and the minimum test procedures to verify compliance with those functional requirements. These test procedures include the following test methods: inspection; analysis/simulation; laboratory tests; demonstrations; and, field/flight tests. For certain requirements more than one method may be indicated. Definitions of each of these verification methods are provided below.

Table 3.7.3.4 ASD Capabilities and Requirements

	OPERATIONAL ENHANCEMENT Operational Capabilities	Key Words	Level 1 Narrative Operational Requirement	Joint Industry/Government CONOPS Capabilities Appendix B
7	**Airport Surface Display for the Controller**			**B7**
7.1	Service providers use a surface situation display that depicts the airport surface and nearby airspace with data tags (ID, type, heading, speed) and GPS derived position for all aircraft and airport vehicles.	Display	1.9, 3.24, 3.29, 3.30, 3.31, 3.32, 3.42	3.2

Table 3.7.3.4-2 ASD Functional Allocation of Operational Requirements

Level I #	ATS 2005 Statement (Level I Need)	C	N	S	W	A	M
1.9	Replacement of Host … transition to satellite navigation …new display platforms!!Key Words: host navigation display		N			A	
3.24	This system's processes and displays provide complete data connectivity between the service provider, flight deck, airline operations center, ramp, airport operator, and airport emergency centers.	C				A	M
3.29	Visual cues that service providers currently rely upon are augmented with enhanced situation displays and surface detection equipment.!!Key Words: separation			S		A	
3.30	Service providers can display satellite-derived position data transmitted by selected flights upon request, while ground-based surveillance data is shared with users as a safety enhancement for preventing incursions.	C		S		A	
3.31	Situation displays are available for airborne and surface traffic, with appropriate overlaps for viewing arriving and departing traffic.	C		S		A	
3.32	The surface situation display depicts the airport and nearby airspace, with data tags for all flights and vehicles			S		A	
3.42	In 2005, ramp service providers, where used, sequence and meter aircraft movement at gates and on ramps, using situation displays that interface with decision support systems and personnel in the control tower.!!Key Words: separation	C		S		A	M

Table 3.7.3.4-3 ASD Functional Requirement and Verification Definitions

Insp	Inspection	Verification is based the determination that the system specification includes the requirement, the system was developed to include the capabilities of the requirement, and an examination of the system shows that the capabilities to meet the requirement were included. Results show that the required capability is in the system to the extent verifiable by inspection only.
A/S	Analysis / Simulation	Verification is based on analysis of the developed system capability. This analysis includes desk checking of characteristics and simulation. Operation of the system is not required. Results show that the specified capability, to the extent possible using analysis and simulation, was developed in the system in such a way the required capability is achievable.
Lab	Laboratory Test	Verification is based on operation of the system (in part or as a whole) in a laboratory environment. Some laboratory equipment may be used in place of operational equipment. Results show that specific required capabilities are achievable using the developed system (in part or as a whole) with laboratory instruments used for measurement and stimulation.
Demo	Demonstration Test	Verification is based on operation of the system (in part or as a whole) using operational equipment. Laboratory equipment is not used. Results show that the selected capability is observed using system components.
Field	Field Test	Verification is based on operation of the system using operational equipment in an operational environment. Results show that the selected capability is repeatedly demonstrable in an operational environment
Validation	Validation Test	Verification is based on operation of the system using operational equipment in an operational environment. Results of the comprehensive evaluation of thorough performance testing show that the full scope of the capability is achieved and is repeatable.

Table 3.7.3.4-4 ASD Functional Requirement and Verification Procedures

Number	Functional Requirement	Insp	A/S	Lab	Demo	Field
7S-1	ASD shall receive ADS-B aircraft and airport surface vehicle tracks from the ATC surveillance system track file.			X	X	X
7S-2	ADSE data shall only be used by the ATC surveillance system to reinforce the ADS-B tracks in the surveillance track file. In the event that an ASDE target exists which does not have a corresponding ASD-B track, it shall be included in the track file as "unidentified" and processed as a surface vehicle target.			X		
7A-1	ASD shall automatically convert all ADS-B aircraft and surface vehicle states into display coordinates.			X	X	
7A-2	ASD shall automatically convert all "unidentified" ASDE tracks states into display coordinates and shall assume that the track belongs to a surface vehicle.			X	X	
7A-3	ASD shall automatically convert all airport and local airspace maps into display coordinates.				X	
7A-4	ASD shall automatically process all display inputs from the controller. These inputs shall at a minimum include control of display brightness, contrast, zoom, coordinates and on/off controls.	X		X	X	
7A-5	ASD shall automatically display the locations, identity, heading, speed, and altitude or on-surface indication for all aircraft below 1000 feet and all airport surface .vehicles. In the event of an "unidentified" ASDE target, a special unambiguous tag shall be assigned indicating that the target is "unidentified."			X	X	
7A-6	ASD shall automatically display all alerts from the ATC automation system to the controller.			X	X	
7A-7	ASD shall automatically display all available local weather from the ATC automation system to the controller. The controller shall have the capability to suppress this weather information at his or her discretion.			X		X
7OM-1	The ASD system shall monitor the inputs received from data sources to determine the integrity/reasonableness of the aircraft and surface vehicle states and the map data received.			X		
7OM-2	The ASD system shall monitor its own operational status and shall automatically report any malfunctions to the ATC Maintenance Monitoring system.			X		

3.8 ADS-B Surveillance in Non-Radar Airspace (ADS-B/NRA) Functional Specification

This functional specification for the ADS-B/NRA consists of a detailed description of the ADS-B/NRA system concept, a presentation of the ADS-B/NRA functional requirements for each of the major ATC functions (i.e., Communications, Navigation, Surveillance, Weather, Automation, and Maintenance and Operations), and, an elaboration of the ADS-B/NRA functional design including functional flow diagrams and interface requirements.

3.8.1 ADS-B/NRA System Concept

The ADS-B/NRA concept consists of a definition of the operational concept, the capabilities, and the expected benefits. Within the operational concept, the ADS-B/NRA mission and modes of operation are also defined. Figure 3.8.1-1 illustrates the ADS-B/NRA concept and shows that it consists primarily of data collection, processing, distribution, and display functions. In essence, information that will enhance a controller's and/or pilot's awareness of the identity, position, speed and heading of aircraft not under radar surveillance is distributed to pilots, non-radar control facilities and to ATC automation. ADS-B/NRA performs surveillance of aircraft in non-radar airspace using the information made available from the air-to-air mode and the air-to-ground mode of ADS-B.

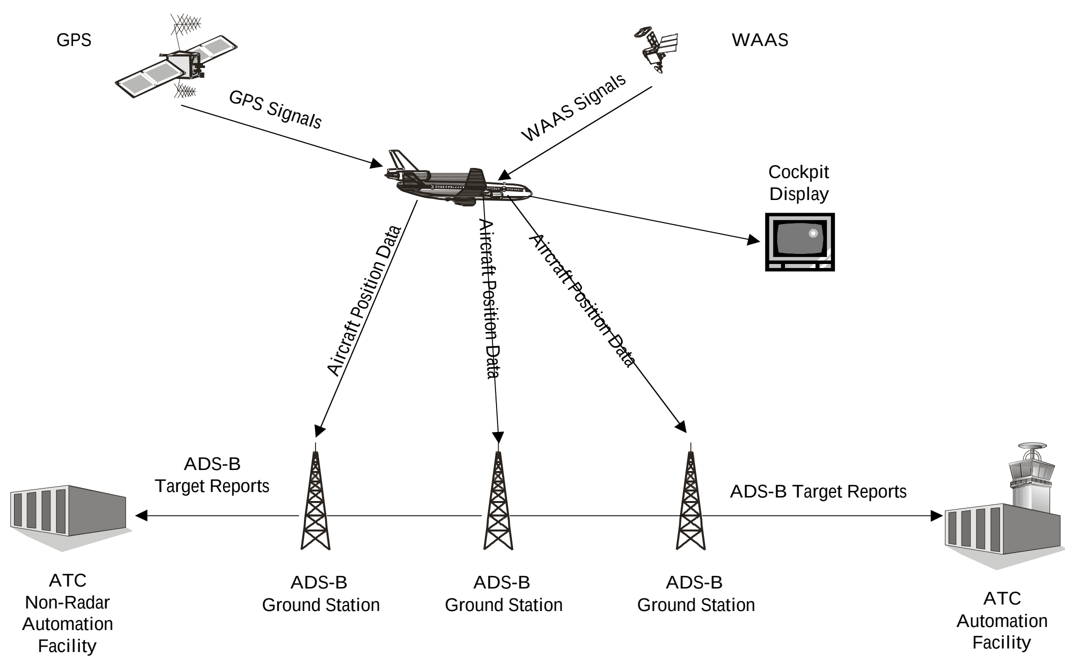


Figure 3.8.1-1 ADS-B/NRA System Concept

3.8.1.1 ADS-B/NRA Operational Concept

In today's system there is airspace that is outside of radar coverage due to the expense of providing radar coverage in some locations. The lack of surveillance information limits the ability of the controller to provide radar separation services and requires that procedural separation be used. This type of separation limits both airport and airspace capacity.

ADS-B for Surveillance in Non-Radar Airspace provides information needed by controllers and pilots to operate more safely during all phases of flight when not under radar surveillance. Aircraft will be equipped with ADS-B using augmented GPS derived positions. This capability will provide additional air-to-air and air-to-ground surveillance coverage and will fill the gaps in radar coverage. Ultimately, ADS-B capabilities will be examined to determine how ADS-B could eventually lead to replacement of beacon radar.

3.8.1.1.1 Mission

Airspace exists in the NAS where there is no coverage from primary or secondary/beacon radar. This forces controllers to implement non-radar/procedural separation standards when controlling IFR traffic in non-radar airspace. The result limits airspace and airport capacity. Thus, the mission of the ADS-B/NRA system can be stated as:

Provide aircraft surveillance information to the ATC automation system, pilots, and to controllers using ADS-B in non-radar airspace.

3.8.1.1.2 Modes of Operation

The ADS-B/NRA modes of operation include the air-side mode and the ground-side mode. In the air-side mode, pilots use the ADS-B information from other aircraft coupled with a CDTI to enhance situational awareness and to perform self-separation, station-keeping and other maneuvers when such maneuvers are delegated to the pilot by the controller.

In the ground-side mode, ADS-B surveillance information is processed to develop ADS-B target reports that are then disseminated to ATC Automation and to ATC facilities. This data will enable IFR separation standards in non-radar airspace to be reduced.

3.8.1.2 ADS-B/NRA Capabilities

The implementation of ADS-B/NRA provides the following operational capabilities:

- Improved positional accuracy and gap-filler coverage with dependent surveillance enhances conflict detection and the service provider's ability to sequence aircraft at arriving terminals
- Use ADS-B to provide position and velocity information for areas where surveillance radar is not affordable providing reduces separation minima in comparison to procedural separation
- Use ADS-B as pseudo-radar for non-radar airports

- Increased traffic surveillance coverage outside radar coverage using ADS-B to increase airport capacity and safety
- Increased pilot situational awareness in non-radar airspace and capability to assume certain delegated control functions.

3.8.1.3 ADS-B/NRA Benefits

The improved ADS-B/NRA is expected to produce the following benefits:

- Increase in surveillance coverage
- Increase in access to airspace
- Increase in arrival and departure rates
- Reduction in flight delays and distance flown
- Increase in predictability for flight times and distances flown
- Reduction in deviations from intended route
- Increased flexibility in route flown

3.8.2 ADS-B/NRA Functional Requirements

The functional requirements for ADS-B/NRA have been developed by first considering the ADS-B/NRA capabilities and then determining the relevant operational needs as stated in the ATS 2005 CONOPS Narrative. The operational capabilities and needs were then analyzed to determine the ATC functions, which were required to satisfy the need. These ADS-B/NRA operational requirements are presented as requirements traceability matrices in Section 3.8.3.4 and are summarized for each of the major ATC functions in the following paragraphs.

3.8.2.1 Communications

The communications requirements for ADS-B/NRA are primarily associated with transmitting and receiving ADS-B broadcasts of aircraft-state both in the air and at the ADS-B ground site. A minimum of voice communications between the pilot and controller is assumed in non-radar airspace. An analysis of the detailed communications requirements contained in the requirements traceability matrix (Section 3.8.3.4) coupled with an examination of the required capabilities results in the following set of communications functional requirements:

1. The air-side element of ADS-B/NRA shall receive own aircraft position and velocity from GPS which may be augmented with LAAS and/or WAAS and shall broadcast ACID, Position, and velocity in the standardized ADS-B formats
2. The air-side element of ADS-B/NRA shall receive the ADS-B states of other aircraft
3. The air-side element of ADS-B/NRA shall communicate operation in a degraded navigational mode to the ground based ATC system when this situation occurs.
4. Voice communications shall be available between the pilot and the controller in non-radar airspace.
5. The ground-side element of ADS-B/NRA shall receive the ADS-B broadcast of aircraft states at all ADS-B ground stations within range of the broadcast

3.8.2.2 Navigation

The ADS-B/NRA requires precise navigational information that uses satellite or augmented satellite information to derive position. An analysis of the detailed navigational requirements contained in the requirements traceability matrix results in the following set of navigational functional requirements:

1. The air-side element of ADS-B/NRA system shall receive its navigational position from GPS, when available.
2. The navigational position information shall be able to include WAAS and LAAS satellite information, when available.
3. If GPS is not available, the aircraft shall use an appropriate area navigation instrument to provide an input to the air-side element of the ADS-B/NRA processor and shall declare a degraded mode of operation.

3.8.2.3 Surveillance

ADS-B/NRA has no direct ATC radar surveillance requirements. ADS-B/NRA does however depend upon ADS-B broadcasts of aircraft state that includes identity, position, and velocity. It also depends upon a suitable set of ADS-B ground stations strategically placed to provide coverage of the non-radar airspace. An analysis of the detailed surveillance requirements contained in the requirements traceability matrix (Section 3.8.3.4) coupled with an examination of the required ADS-B/NRA capabilities results in the following set of airborne surveillance functional requirements:

1. ADS-B/NRA air-side and ground-side shall receive ADS-B broadcasts of aircraft state.
2. ADS-B/NRA air-side element shall broadcast its own aircraft state for use by the ground ATC surveillance system and for air-to-air surveillance by other properly equipped aircraft.
3. The ADS-B ground-side element shall consist of a sufficient number of ground stations to provide coverage of the non-radar airspace.
4. The ADS-B ground-element shall provide ADS-B surveillance data to ATC automation and to non-radar ATC facilities. ATC automation shall provide a smooth from radar controlled airspace to ADS-B non-radar controlled airspace.
5. The ADS-B ground-element shall not provide tracked information but will only provide correlated ADS-B target reports.

3.8.2.4 Weather

ADS-B/NRA does not have any directly related functional requirements in the weather area

3.8.2.5 Automation

The automation functions required by ADS-B/NRA involve the processing of: ADS-B aircraft state information; ADS-B target processing and display on-board the aircraft; ADS-B processing and distribution of target reports to ATC automation systems and to non-radar facilities. ATC automation is not considered part of the ADS-B/NRA system but it is recognized that it must coordinate with the ADS-B/NRA operational enhancement. Analysis of the detailed automation requirements contained in the requirements traceability matrix (Section 3.8.3.4) coupled with an examination of the required ADS-B/NRA capabilities results in the following set of airborne automation functional requirements:

1. The ADS-B/NRA air-side element shall automatically convert all ADS-B aircraft states into own aircraft relative coordinates
2. The ADS-B/NRA air-side element shall automatically process all display inputs from the pilot. These inputs shall at a minimum include control of display brightness, contrast, location of own aircraft on the display, and on/off controls.
3. ADS-B/NRA shall automatically inform the ground based ATC system of operation in a degraded mode
6. The ground-side element of ADS-B/NRA shall perform ADS-B ground station-to-station correlation of the received aircraft states from all stations within range of the broadcasting aircraft.
7. The ground-side element of ADS-B/NRA shall develop ADS-B target reports based on the correlated aircraft state data from one or more ADS-B ground stations.
8. The ground-side element of ADS-B/NRA shall format the target reports for distribution over whatever ground-to-ground media are available for communications with the ATC facilities of interest.
9. The ground-side element of ADS-B/NRA shall distribute the ADS-B target reports according to a set of ATC Facility Coverage Maps to those ATC automation and to non-radar facilities that have responsibility for a given aircraft. This shall be accomplished by filtering the target reports based on aircraft location and facility area of responsibility.

3.8.2.6 Operations and Maintenance

1. The ADS-B/NRA air-side and ground-side system elements shall monitor the inputs received from the navigational source as well as to determine the integrity/reasonableness of the aircraft state messages received.
2. The ADS-B/NRA air-side and ground-side system elements shall monitor its own operational status and shall automatically report any malfunctions to the ATC system.

3.8.3 ADS-B/NRA Functional Design

This Section presents the functional design for the ADS-B/NRA that will satisfy the requirements and provide the capabilities previously described. In addition, the ADS-B/NRA data flow will also be discussed as part of the overall functional design. To begin, consider the functional flow chart for the ADS-B/NRA functional design presented as Figure 3.8.3-1.

3.8.3.1 System Functional Relationships

The ADS-B/NRA primary inputs for both modes of operation are from the ADS-B broadcasts of aircraft state. The air-side mode also receives own aircraft state from the GPS/WAAS receiver. The GPS/WAAS constellation provides signals in space which are received by the GPS/WAAS receiver and processed to determine own aircraft position and velocity. This information is then broadcast using the ADS-B datalink and formats for reception by the ground and by other aircraft. The air-side mode then uses own state to convert the states of the other ADS-B aircraft to a set of coordinates relative to own aircraft. This information is then forwarded to the CDTI Display Generator for the development of appropriate display driver commands. Other inputs to the CDTI display generator are in the form of display commands from the pilot. These commands include items such as zoom control, location of own aircraft on the display, brightness and contrast, on/off controls, and alarm controls.

The ground-side mode of the ADS-B/NRA starts with the reception of the ADS-B broadcasts from aircraft within coverage of a ground site. There are expected to be several ground sites providing coverage for a given segment of non-radar airspace so that several ground stations may receive the same broadcast from a single aircraft. Thus, the received ADS-B messages must be correlated to eliminate duplicate broadcasts from the same aircraft. This is accomplished with a station-to-station correlator. The correlated ADS-B messages are then formed into a set of ADS-B target reports, which are formatted for distribution to ATC automation and to ATC facilities. In order that the facilities with responsibility for the ADS-B covered airspace receive the proper target reports, it is necessary that the ground-side compare the target reports to ATC facilities coverage maps and sends the proper reports to the appropriate facilities.

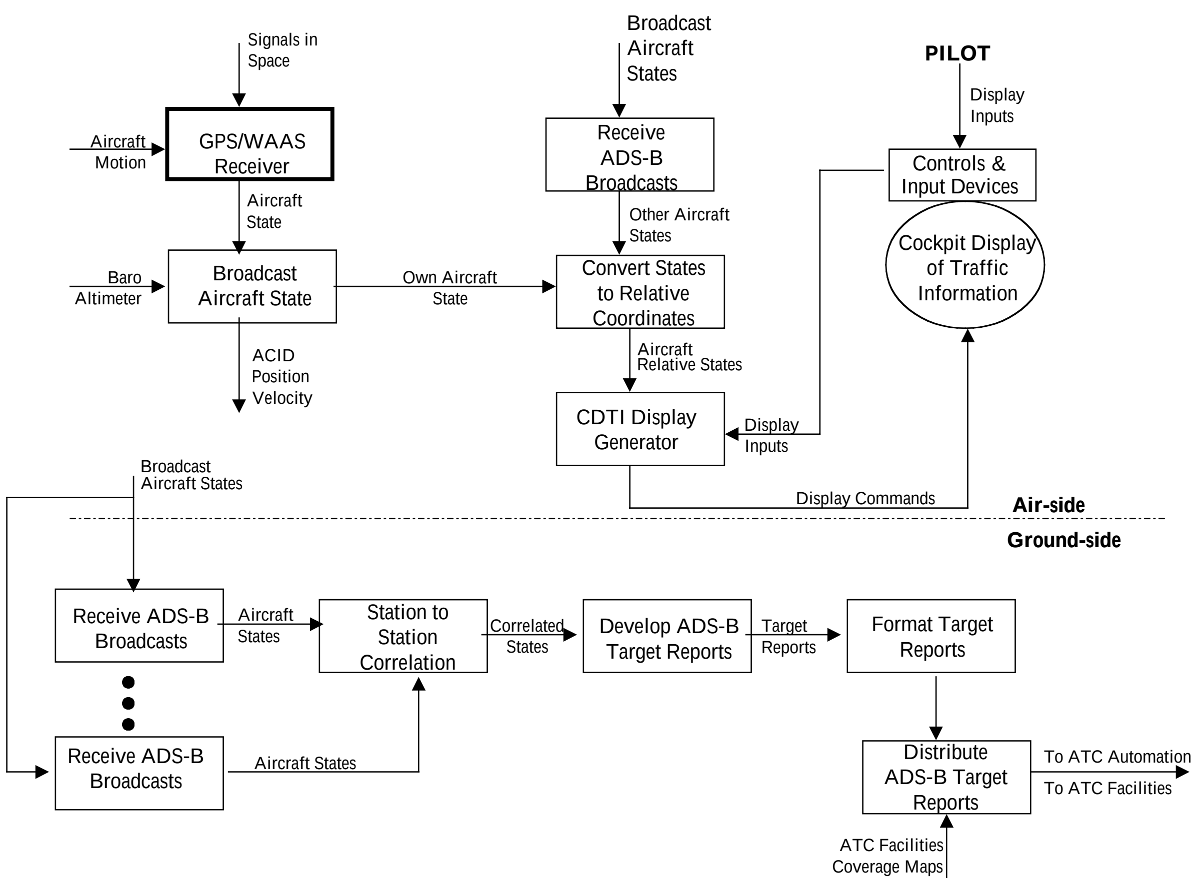


Figure 3.8.3-1 ADS-B/NRA Functional Block Diagram

3.8.3.2 Interface Requirements

Examining the ADS-B/NRA functional design illustrated in Figure 3.8.3-1 one observes that there are four major inputs to the ADS-B/NRA. The first is aircraft states from the ADS-B broadcasts. The second is own aircraft state from the GPS/WAAS Receiver. The third interface is with the ATC automation and ATC facilities that are designated to receive the ADS-B/NRA data.. Several interfaces also exist within the ADS-B/NRA enhancement among the ADS-B/NRA functional elements. Both the internal and external ADS-B/NRA interfaces are identified in the following paragraphs.

3.8.3.2.1 Internal Interfaces

Internal interfaces include:

- ADS-B/NRA Ground-side Processor/ATC Facilities Database - specific airport map characteristics including runways, taxiways, and gate locations
- ADS-B Air-side Transmitters/ADS-B Ground-side Receivers - receive all ADS-B broadcast messages within the coverage of the ADS-B Ground Station.
- ADS-B/NRA Ground-side Processor/ Broadcast Aircraft States - receive all ADS-B broadcast messages within the coverage of the ADS-B Ground Station.
- ADS-B Air-side Transmitters/ ADS-B Air-side Receivers - to receive all B broadcast messages within range.

3.8.3.2.2 External Interfaces

External interfaces include ADS-B/NRA interfaces with:

- GPS/WAAS Receiver
- ADS-B Broadcast Messages from other aircraft
- ADS-B Transmitter
- Communications medium used for ADS_B target reports to ATC Facilities and ATC Automation
- CDTI

3.8.3.3 Human Factors Considerations

The human factors considerations for ADS-B/NRA are only concerned with the design of the CDTI. The CDTI is not considered part of the ADS-B/NRA enhancement but must provide the inputs to this display. No other human factors considerations are pertinent to this enhancement.

3.8.3.4 ADS-B/NRA Requirements Traceability Matrices

Three aspects of requirements traceability are provided in this section. The first provides traceability between the ADS-B/NRA capabilities and the operational requirements as stated in the ATS 2005 CONOPS Narrative and the Joint Government/Industry Operational Concept. The second provides the functional allocation of the operational requirements derived from the ATS 2005 Narrative to the major ATC functions (i.e., communications, navigation, surveillance, weather, automation, maintenance and operations). The third aspect provides a recommended requirement validation methodology for each of the functional requirements identified in Section 3.8.2.

3.8.3.4.1 Capabilities to CONOPS Traceability

These operational requirements are derived from the ATS 2005 CONOPS Narrative. They have been developed based upon key word searches of the ATS 2005 Operational Needs database. The key words used in these searches were based on the ADS-B/NRA capability descriptions obtained from the RTCA roadmap. Each ADS-B/NRA operational requirement is related to at least one ADS-B/NRA capability. Table 3.8.3.4-1 provides traceability between the ADS-B/NRA capabilities and the operational requirements. In addition, the cross reference of Government/Industry Operational Concept for the Evolution of Free Flight provided as Appendix B of the Joint Government/Industry Roadmap for Free Flight Operational Enhancements was used to provide traceability between the ADS-B/NRA capabilities and the RTCA requirements. This mapping is also provided as a column in Table 3.8.3.4-1.

3.8.3.4.2 Operational to Functional Requirement Traceability

Table 3.8.3.4-2 provides the functional allocation of the set of ADS-B/NRA operational requirements derived from the ATS 2005 CONOPS Narrative. It must be noted that the requirements obtained in this manner are not all directly related to the ADS-B/NRA since they apply to the broader NAS. They are included however for completeness since they result from the searches associated with each ADS-B/NRA capability are part of the basis for the derived functional requirements presented in Section 3.8.2.

3.8.3.4.3 Procedures for Functional Requirement Verification

Table 3.8.3.4-3 provides the list of ADS-B/NRA functional requirements presented in Section 3.8.2 and the minimum test procedures to verify compliance with those functional requirements. These test procedures include the following test methods: inspection; analysis/simulation; laboratory tests; demonstrations; and, field/flight tests. For certain requirements more than one method may be indicated. Definitions of each of these verification methods are provided below.

Table 3.8.3.4-1 ADS-B/NRA Capabilities and Requirements

	OPERATIONAL ENHANCEMENT Operational Capabilities	Key Words	Level 1 Narrative Operational Requirement	Joint Industry/Government CONOPS Capabilities Appendix B
8	**ADS-B Surveillance in Non-Radar Airspace (ADS-B/NRA)**			**B8**
8.1	Improved positional accuracy and gap-filler coverage with dependent surveillance enhances conflict detection and the service provider's ability to sequence aircraft at arriving terminals.	Satellite, Conflict, Sequence	3.30, 4.39, 4.61, 4.62, 5.7, 5.14, 5.41, 6.6, 6.24 1.17, 4.26, 4.29, 5.2, 5.9.2 3.12, 3.36, 3.38, 3.42, 4.2, 4.9, 4.20, 4.38, 4.45, 5.2	4.2, 4.3, 4.3.1, 6.1, 6.1.1
8.2	Use ADS-B to provide position and velocity information for areas where surveillance radar is not affordable providing reduced separation minima in comparison to procedural separation.	Position, Separation	3.30, 4.12, 5.7, 5.18, 5.41, 6.6, 6.7, 6.24 1.16, 1.34, 4.23, 5.6.1, 5.18, 6.3, 6.5, 6.7, 6.12, 6.13	4.2, 4.3, 4.3.1, 6.1, 6.1.1
8.3	Use ADS-B as pseudo-radar for non-radar airports	Satellite	3.30, 4.12, 5.7	4.2, 4.3, 4.3.1
8.4	Increased traffic surveillance coverage outside radar coverage using ADS-B to increase airport capacity and safety.	Satellite, Capacity	3.30, 4.12, 5.7 1.19, 4.43	4.2, 4.3, 4.3.1

Table 3.7.3.4-2 ADS-B/NRA Functional Allocation of Operational Requirements

1.16	Controller workload under peak traffic remains equivalent to the workload controllers absorbed in the 1990s under lighter traffic demand. This increased ATC efficiency has been achieved through the implementation of decision support systems for traffic management and control, dynamic alteration of airspace boundaries, reduced vertical separation minima, improved air/ground communications and coordination, and enhanced ground/ground coordination aids.!!Key Words: decision support systems airspace boundaries vertical separation communications coordination	C				A	
1.17	Air safety has been increased through the implementation of conflict detection and resolution tools, the inclusion of the flight deck in some separation decision-making, and greatly enhanced weather detection and reporting capabilities. !!Key Words: conflict detection resolution separation weather !!	C		S	W	A	
1.19	Phased Technology Implementation. The evolution of the operational environment is based on an incremental implementation of new technologies. This approach maintains safety as the first priority, while also increasing capacity, efficiency, and flexibility in a balance with environmental considerations. !!Key Words: safety capacity efficiency flexibility	C	N	S	W	A	M
1.34	These tools reduce the burden of routine tasks while increasing the provider's ability to evaluate traffic situations and plan the appropriate response. This increases productivity and provides greater flexibility to user operations, with potential reduced vertical separation minima and increased traffic density.					A	
3.12	For departures, taxi time updates and the associated estimates included in the taxi plan are coordinated automatically with airspace automation to efficiently sequence ground traffic to match projected traffic flows aloft.!!Key Words: taxi (within 10 words of)Update or taxi Plan	C				A	
3.30	Service providers can display satellite-derived position data transmitted by selected flights upon request, while ground-based surveillance data is shared with users as a safety enhancement for preventing incursions.	C		S		A	
3.36	As the aircraft prepares to taxi, service providers use decision support systems to determine taxi sequencing, and to perform conformance monitoring and conflict checking.			S		A	
3.38	For departures, the decision support system incorporates departure times, aircraft type, wake turbulence criteria, and departure routes to safely and efficiently sequence aircraft to the departure threshold.!!Key Words: departure (in the same paragraph as) DSS					A	
3.42	In 2005, ramp service providers, where used, sequence and meter aircraft movement at gates and on ramps, using situation displays that interface with decision support systems and personnel in the control tower.!!Key Words: separation	C		S		A	M

4.2	Decision support systems increase the efficient use of airport assets by providing assistance in planning taxi sequences and spacing, and in the assignment of aircraft to runways.					A	
4.9	Decision support systems assist the service provider in providing runway assignments and in merging and sequencing traffic, based on accurate traffic projections and user preferences.!!Key Words: (or) decision support systems automation	C		S	W	A	
4.12	Satellite-based position data, broadcast by properly equipped aircraft, are used in cockpit traffic displays to increase the pilots' situation awareness for aircraft-to-aircraft separation. These avionics allow an increasingly frequent transfer of responsibility for separation assurance to the flight deck for some types of operations.!!Key Words: self separation!!	C	N	S		A	
4.20	Decision support systems help service providers to maintain situation awareness, identify and resolve conflicts, and sequence and space arrival traffic.!!Key Words: decision support systems –or- automation in the same paragraph as) conflicts –or- separation –or- sequence!!	C		S	W	A	
4.23	Visual separation by pilots in terminal areas is expanded to allow all-weather pilot separation when deemed appropriate by the service provider.	C		S	W	A	
4.26	Situation displays and conflict alert functions have evolved to provide more information, based on expanded data acquisition capabilities and improved trajectory modeling and analysis!!Key Words: display (in the same paragraph as) conflict!!	C		S		A	
4.29	With these data, improved trajectory models and analyses benefit the service provider through highly accurate conflict detection functions, and reliable conflict resolutions !!Key Words: (or) conflict detection conflict resolution	C		S		A	
4.38	Departure and arrival planning services involve the sequencing and spacing of arrivals, and the integration of departures into the airborne traffic environment.!!Key Words: departure planning arrival Planning	C		S		A	
4.39	Improved departure flows are achieved through tools that provide more efficient airport surface operations, improved real time assessment of traffic activity in departure and en route airspace, and expanded usage of flexible routes based on RNAV, satellite navigation, and FMS.!!Key Words: departure flow	C	N	S		A	
4.43	In the final portion of the arrival phase, decision support systems facilitate the use of time-based metering to maximize airspace and airport capacity.	C		S		A	
4.45	On final approach, the service provider may give the pilot responsibility for station keeping to maintain the required sequence and spacing to the runway.	C	N	S		A	
4.61	Satellite navigation allows aircraft to fly more flexible routes		N			A	
4.62	Approach guidance, currently provided by ground-based systems, is supplemented by satellite-based approaches !!Key Words: approach guidance		N			A	

5.2	Improved decision support tools for conflict detection, resolution, and flow management allow increased accommodation of user-preferred trajectories, schedules, and flight sequences.!!Key Words: DSS or automation) in the same paragraph as (conflict or flow)	C		S	W	A	
5.6.1	Structured routes are the exception rather than the rule, and exist only when required to meet continuous high density, to provide for the avoidance of terrain and active SUAs, and to facilitate the transition between areas with differing separation standards.					A	M
5.7	Surveillance of all positively controlled aircraft is provided by a combination of primary and secondary radar, and the broadcast of satellite-derived position information by individual flights.!!Key Words: surveillance	C		S		A	
5.9.2	New displays are operational in all en route facilities and the service provider has access to more accurate forecasts of potential conflicts.!!Key Words: display (in the same paragraph as) conflict			S		A	
5.14	An increasing number of aircraft are equipped with satellite based navigation, digital communications, and the capability to automatically transmit position data.	C	N	S		A	
5.18	Separation standards depend on the flight's equipage and the quality of the positional data, service provider displays indicate the quality of the resulting aircraft positions and the appropriate equipage information. !!Key Words: separation Standards	C		S		A	
5.41	For VFR aircraft automatically reporting their satellite-derived positions … coupled with access to the flight's data via the NAS-wide information system, reduces the workload associated with providing traffic advisories to uncontrolled aircraft.!!Key Words: traffic advisories	C	N	S		A	M
6.3	Procedural reductions in separation standards are facilitated through the improved infrastructure.!!Key Words: separation Standards	C	N	S		A	
6.5	Oceanic separation minima are significantly reduced.	C	N	S		A	
6.6	Satellite navigation systems and datalink allow more accurate and frequent traffic position updates; datalink and expanded radio coverage provide direct air-to-ground communications (both digital and voice).!!Key Words: navigation	C	N	S		A	
6.7	Real time position data and continuously updated trajectory projections virtually eliminate manual control procedures in Oceanic airspace … Oceanic separation standards and procedures are derived from radar control techniques.	C		S		A	
6.12	Reduced separation minima and dynamic management of route structures help the user formulate and request a preferred flight profile.	C	N	S		A	
6.13	Most aircraft navigate using a global satellite navigation system whose improved accuracy generates the required safety for reduced separation standards.		N				
6.24	Aircraft position updates are supplied by the aircraft's broadcast of satellite navigation-derived position data transmissions.!!Key Words: position reports	C	N	S		A	

Table 3.8.3.4-3 ADS-B/NRA Functional Requirement and Verification Definition

Insp	Inspection	Verification is based the determination that the system specification includes the requirement, the system was developed to include the capabilities of the requirement, and an examination of the system shows that the capabilities to meet the requirement were included. Results show that the required capability is in the system to the extent verifiable by inspection only.
A/S	Analysis / Simulation	Verification is based on analysis of the developed system capability. This analysis includes desk checking of characteristics and simulation. Operation of the system is not required. Results show that the specified capability, to the extent possible using analysis and simulation, was developed in the system in such a way the required capability is achievable.
Lab	Laboratory Test	Verification is based on operation of the system (in part or as a whole) in a laboratory environment. Some laboratory equipment may be used in place of operational equipment. Results show that specific required capabilities are achievable using the developed system (in part or as a whole) with laboratory instruments used for measurement and stimulation.
Demo	Demonstration Test	Verification is based on operation of the system (in part or as a whole) using operational equipment. Laboratory equipment is not used. Results show that the selected capability is observed using system components.
Field	Field Test	Verification is based on operation of the system using operational equipment in an operational environment. Results show that the selected capability is repeatedly demonstrable in an operational environment
Validation	Validation Test	Verification is based on operation of the system using operational equipment in an operational environment. Results of the comprehensive evaluation of thorough performance testing show that the full scope of the capability is achieved and is repeatable.

Table 3.8.3.4-4 ADS-B/NRA Functional Requirement and Verification Procedures

8C-1	The air-side element of ADS-B/NRA shall receive own aircraft position and velocity from GPS which may be augmented with LAAS and/or WAAS and shall broadcast ACID, Position, and velocity in the standardized ADS-B formats.			X	X	X
8C-2	The air-side element of ADS-B/NRA shall communicate operation in a degraded navigational mode to the ground based ATC system when this situation occurs.		X	X		
8C-3	The air-side element of ADS-B/NRA shall receive the ADS-B states of other aircraft.				X	X
8C-4	Voice communications shall be available between the pilot and the controller in non-radar airspace.	X			X	
8C-5	The ground-side element of ADS-B/NRA shall receive the ADS-B broadcast of aircraft states at all ADS-B ground stations within range of the broadcast.		X		X	
8N-1	The air-side element of ADS-B/NRA system shall receive its navigational position from GPS, when available.				X	X
8N-2	The navigational position information shall be able to include WAAS and LAAS satellite information, when available.			X		
8N-3	If GPS is not available, the aircraft shall use an appropriate area navigation instrument to provide an input to the air-side element of the ADS-B/NRA processor and shall declare a degraded mode of operation.			X	X	
8S-1	ADS-B/NRA air-side and ground-side shall receive ADS-B broadcasts of aircraft state.			X	X	X
8S-2	ADS-B/NRA air-side element shall broadcast its own aircraft state for use by the ground ATC surveillance system and for air-to-air surveillance by other properly equipped aircraft.			X		X
8S-3	The ADS-B ground-element shall provide ADS-B surveillance data to ATC automation and to non-radar ATC facilities. ATC automation shall provide a smooth from radar controlled airspace to ADS-B non-radar controlled airspace.			X	X	
8S-4	The ADS-B ground-side element shall consist of a sufficient number of ground stations to provide coverage of the non-radar airspace.		X		X	
8S-5	The ADS-B ground-element shall not provide tracked information but will only provide correlated ADS-B target reports	X			X	
8A-1	The ADS-B/NRA air-side element shall automatically convert all ADS-B aircraft states into own aircraft relative coordinates.		X	X	X	X
8A-2	The ADS-B/NRA air-side element shall automatically process all display inputs from the pilot. These inputs shall at a minimum include control of display brightness, contrast, location of own aircraft on the display, and on/off controls.	X		X	X	
8A-3	ADS-B/NRA shall automatically inform the ground based ATC system of operation in a degraded mode.		X	X		
8A-4	The ground-side element of ADS-B/NRA shall perform ADS-B ground station-to-			X		X

	station correlation of the received aircraft states from all stations within range of the broadcasting aircraft.					
8A-5	The ground-side element of ADS-B/NRA shall develop ADS-B target reports based on the correlated aircraft state data from one or more ADS-B ground stations.			**X**	**X**	
8A-6	The ground-side element of ADS-B/NRA shall format the target reports for distribution over whatever ground-to-ground media are available for communications with the ATC facilities of interest.			**X**		
8A-7	The ground-side element of ADS-B/NRA shall distribute the ADS-B target reports according to a set of ATC Facility Coverage Maps to those ATC automation and to non-radar facilities that have responsibility for a given aircraft. This shall be accomplished by filtering the target reports based on aircraft location and facility area of responsibility.			**X**	**X**	
8OM-1	The ADS-B/NRA air-side and ground-side system elements shall monitor the inputs received from the navigational source as well as to determine the integrity/reasonableness of the aircraft state messages received.			**X**		
8OM-2	The ADS-B/NRA air-side and ground-side system elements shall monitor its own operational status and shall automatically report any malfunctions to the ATC system.			**X**		
8A-3	ADS-B/NRA shall automatically inform the ground based ATC system of operation in a degraded mode.		**X**	**X**		
8A-4	The ground-side element of ADS-B/NRA shall perform ADS-B ground station-to-station correlation of the received aircraft states from all stations within range of the broadcasting aircraft.			**X**		**X**
8A-5	The ground-side element of ADS-B/NRA shall develop ADS-B target reports based on the correlated aircraft state data from one or more ADS-B ground stations.			**X**	**X**	
8A-6	The ground-side element of ADS-B/NRA shall format the target reports for distribution over whatever ground-to-ground media are available for communications with the ATC facilities of interest.			**X**		
8A-7	The ground-side element of ADS-B/NRA shall distribute the ADS-B target reports according to a set of ATC Facility Coverage Maps to those ATC automation and to non-radar facilities that have responsibility for a given aircraft. This shall be accomplished by filtering the target reports based on aircraft location and facility area of responsibility.			**X**	**X**	
8OM-1	The ADS-B/NRA air-side and ground-side system elements shall monitor the inputs received from the navigational source as well as to determine the integrity/reasonableness of the aircraft state messages received.			**X**		
8OM-2	The ADS-B/NRA air-side and ground-side system elements shall monitor its own operational status and shall automatically report any malfunctions to the ATC system.			**X**		

3.9 ADS-B Separation Standards (ADS-B/SS) Functional Specification

This functional specification for the ADS-B/ERA consists of: a detailed description of the ADS-B/SS system concept; a presentation of the ADS-B/SS functional requirements for each of the major ATC functions (i.e., Communications, Navigation, Surveillance, Weather, Automation, and Maintenance and Operations); and, an elaboration of the ADS-B/SS functional design including functional flow diagrams and interface requirements.

3.9.1 ADS-B/SS System Concept

The ADS-B/SS concept consists of a definition of the operational concept, the capabilities, and the expected benefits. Within the operational concept, the ADS-B/SS mission and modes of operation are also defined. Figure 3.9.1-1 illustrates the ADS-B/SS concept and shows that it consists primarily of data collection and processing display functions. In essence ADS-B and radar data are integrated or fused to improve surveillance coverage, accuracy, and update rate. These capabilities will better support automated decision support tools and may lead to reduced separation standards.

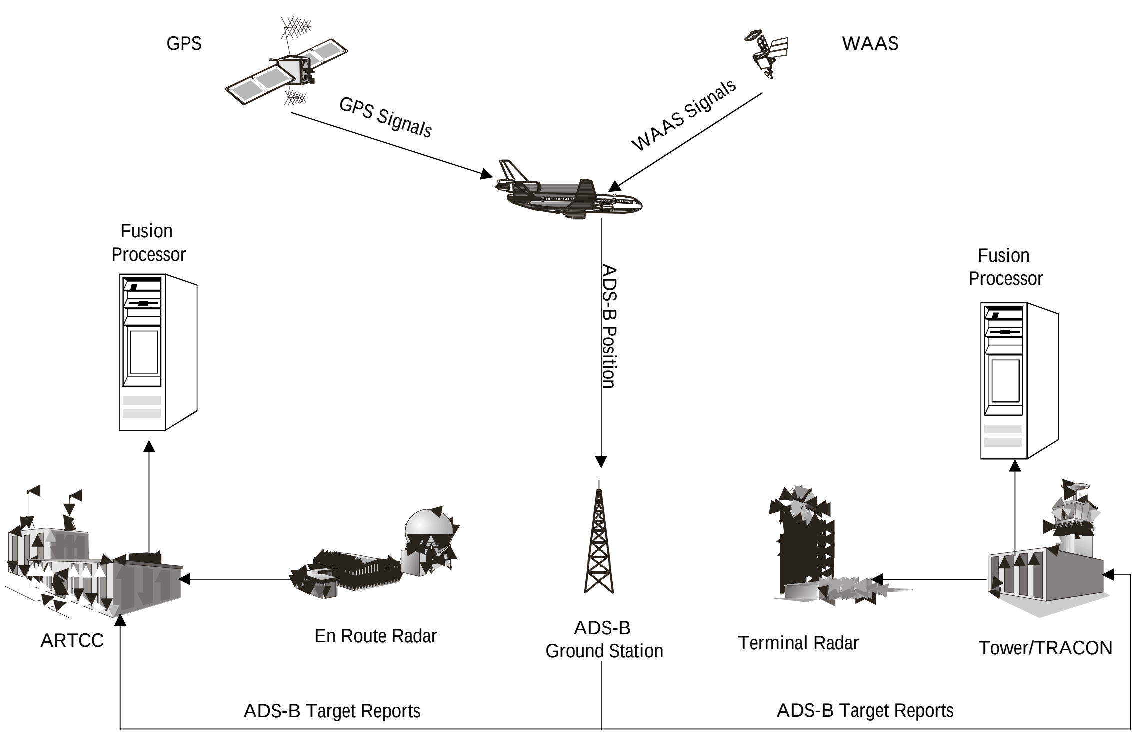


Figure 3.9.1-1: ADS-B/SS System Concept

3.9.1.1 ADS-B/SS Operational Concept

ADS-B/SS will integrate ADS-B data with radar data to determine if separation standards can be reduced. In the near term, ADS-B will be integrated with conflict alert. Ultimately ADS-B will be integrated with advanced decision support tools. The concept of operations consists of the collection of all ADS-B target reports and radar target reports. Primary radar reports will only be used to reinforce the beacon radar reports. Primary only targets will be processed as they are today and will not be included as part of this enhancement. Thus, ADS-B and beacon radar reports will be processed and the data will be integrated to improve accuracy and update rate compared to beacon radar. In addition, when ADS-B data and radar data exists on the same target, this information will be used to automatically calibrate the radar thus reducing radar bias errors and ADS-B/Radar registration errors. This will also improve the radar tracking accuracy on radar only targets. Finally, when there is multiple radar coverage on a single target without ADS-B capability, this multi-radar information will be fused to improve the surveillance of that target.

3.9.1.1.1 Mission

ADS-B and radar coverage of the same airspace will exist. Aircraft will be under surveillance of both ADS-B and beacon radar systems. This provides the opportunity to improve the overall performance of the surveillance system. Thus, the goal of this enhancement effort is to:

Improve aircraft surveillance information by integrating ADS-B and radar surveillance data.

3.9.1.1.2 Modes of Operation

The ADS-B/SS has several modes of operation. The first is single radar tracking, i.e., when an aircraft is not ADS-B equipped or under ADS-B coverage and is being tracked by only one radar. Next, there is multi-radar fusion tracking, i.e., when an aircraft is under coverage of multiple radars but is either not ADS-B equipped or is not under ADS-B coverage. Next, there is the ADS-B Target Tracking Mode, i.e., when an aircraft is only under ADS-B coverage and there is no radar coverage available. Finally, there is the ADS-B/Radar fusion-tracking mode, i.e., when an aircraft is under ADS-B surveillance and under radar surveillance (single or multiple) at the same time. In this last mode, automatic calibration of the radars is performed to improve their tracking capability and to remove registration errors between the ADS-B and the Radar Systems.

3.9.1.2 ADS-B/SS Capabilities

The implementation of ADS-B/SS provides the following operational capabilities:

- The automation system will fuse radar and ADS-B surveillance data for presentation on service provider situation displays
- ADS-B is used to provide more accurate position and velocity information to enhance surveillance tracking and to reduce false alerts declared by tactical conflict detection algorithms that will accommodate a more unstructured flow of traffic.

- ADS-B is used to allow service providers to better provide separation services in areas with radar coverage
- ADS-B is used to improve the radar system accuracy for radar only targets and to remove registration errors between the ADS-B and the Radar systems through automatic radar system calibration

3.9.1.3 ADS-B/SS Benefits

The improved ADS-B/SS is expected to produce the following benefits:

- Increase in surveillance coverage
- Improved surveillance system performance
- Increase in access to airspace
- Reduced separation standards
- Increased capacity through more accurate metering and spacing
- Improved performance of decision support tools

3.9.2 ADS-B/SS Functional Requirements

The functional requirements for ADS-B/SS have been developed by first considering the ADS-B/SS capabilities and then determining the relevant operational needs as stated in the ATS 2005 CONOPS Narrative. The operational capabilities and needs were then analyzed to determine the ATC functions, which were required to satisfy the need. These ADS-B/SS operational requirements are presented as requirements traceability matrices in Section 3.9.3.4 and are summarized for each of the major ATC functions in the following paragraphs.

3.9.2.1 Communications

The communications requirements for ADS-B/SS are primarily associated with receiving ADS-B broadcasts of aircraft-state both at the ADS-B ground site and with receiving the target reports from radars that have overlapping coverage with the ADS-B surveillance system. An analysis of the detailed communications requirements contained in the requirements traceability matrix (Section 3.9.3.4) coupled with an examination of the required capabilities results in the following

1. The ground-side element of ADS-B/ERA shall receive the ADS-B broadcast of aircraft states at all ADS-B ground stations within range of the broadcast
2. The ground-side element of ADS-B/ERA shall receive all radar target reports from radars that overlap the coverage of the ADS-B system

3.9.2.2 Navigation

The ADS-B/SS does not have any direct navigation functional requirements. However, it is assumed that the GPS system or an augmented GPS system is the primary source of all ADS-B broadcasts and that the use of other area navigation systems for the ADS-B input will be identified to the ground element of the ADS-B surveillance system.. An analysis of the detailed navigational requirements contained in the requirements traceability matrix results in the following set of navigational functional requirements:

1. The airside element of ADS-B/SS system shall receive its navigational position from GPS, when available.
2. The navigational position information shall be able to include WAAS and LAAS satellite information, when available.
3. If GPS is not available, the aircraft shall use an appropriate area navigation instrument to provide an input to the airside element of the ADS-B/SS processor and shall declare a degraded mode of operation.

3.9.2.3 Surveillance

ADS-B/SS requires direct ATC radar surveillance target reports in areas where the ADS-B and the radar systems coverage overlap. ADS-B/SS depends upon ADS-B broadcasts of aircraft state that includes identity, position, and velocity. It also requires a suitable set of ADS-B ground stations strategically placed to provide coverage of the ADS-B designated airspace. An analysis of the detailed surveillance requirements contained in the requirements traceability matrix (Section 3.9.3.4) coupled with an examination of the required ADS-B/SS capabilities results in the following set of airborne surveillance functional requirements:

1. ADS-B/SS shall receive ADS-B broadcasts of aircraft state.
2. The ADS-B ground-side element shall consist of a sufficient number of ground stations to provide coverage of the ADS-B designated airspace.
3. The ADS-B/SS shall receive radar target reports from all ATC radars that have coverage of the designated airspace.

3.9.2.4 Weather

ADS-B/SS does not have any directly related functional requirements in the weather area

3.9.2.5 Automation

The automation functions required by ADS-B/SS involve the processing of: ADS-B aircraft state information; processing and correlation of radar target reports with ADS-B target reports; tracking of all targets and fusion tracking of targets with multiple surveillance sensor coverage; and automatic interface with the ATC Surveillance system Track File. Analysis of the detailed automation requirements contained in the requirements traceability matrix (Section 3.9.3.3) coupled with an examination of the required ADS-B/SS capabilities results in the following set of airborne automation functional requirements:

1. The ground-side element of ADS-B/SS shall perform ADS-B ground station-to-station correlation of the received aircraft states from all stations within range of the broadcasting aircraft.
2. The ground-side element of ADS-B/SS shall develop ADS-B target reports based on the correlated aircraft state data from one or more ADS-B ground stations.
3. The ADS-B/SS shall correlate all radar and ADS-B target reports to identify those targets that are ADS-B only, ADS/B and radar, single radar only, and multiple radar.
4. The ADS-B/SS shall provide tracking algorithms for each class of target, i.e., ADS-B only, ADS/B and radar, single radar only, and multiple radar

5. The ADS-B/SS shall provide all target tracks, properly identified, to the ATC Surveillance Track File.
6. The ADS-B/SS shall provide fusion tracking for multi-radar targets and for ADS-B/radar targets. In the case of the ADS-B/radar targets, the ADS-B/SS shall use the redundant information to determine a set of calibration coefficients for the appropriate radar(s).

3.9.2.6 Operations and Maintenance

1. The ADS-B/SS airside and ground-side system elements shall monitor all target report inputs to determine the integrity/reasonableness of the data.
2. The ADS-B/SS ground-side system elements shall monitor its own operational status and shall automatically report any malfunctions to the ATC system.

3.9.3 ADS-B/SS Functional Design

This Section presents the functional design for the ADS-B/SS that will satisfy the requirements and provide the capabilities previously described. In addition, the ADS-B/SS data flow will also be discussed as part of the overall functional design. To begin, consider the functional flow chart for the ADS-B/SS functional design presented as Figure 3.9.3-1.

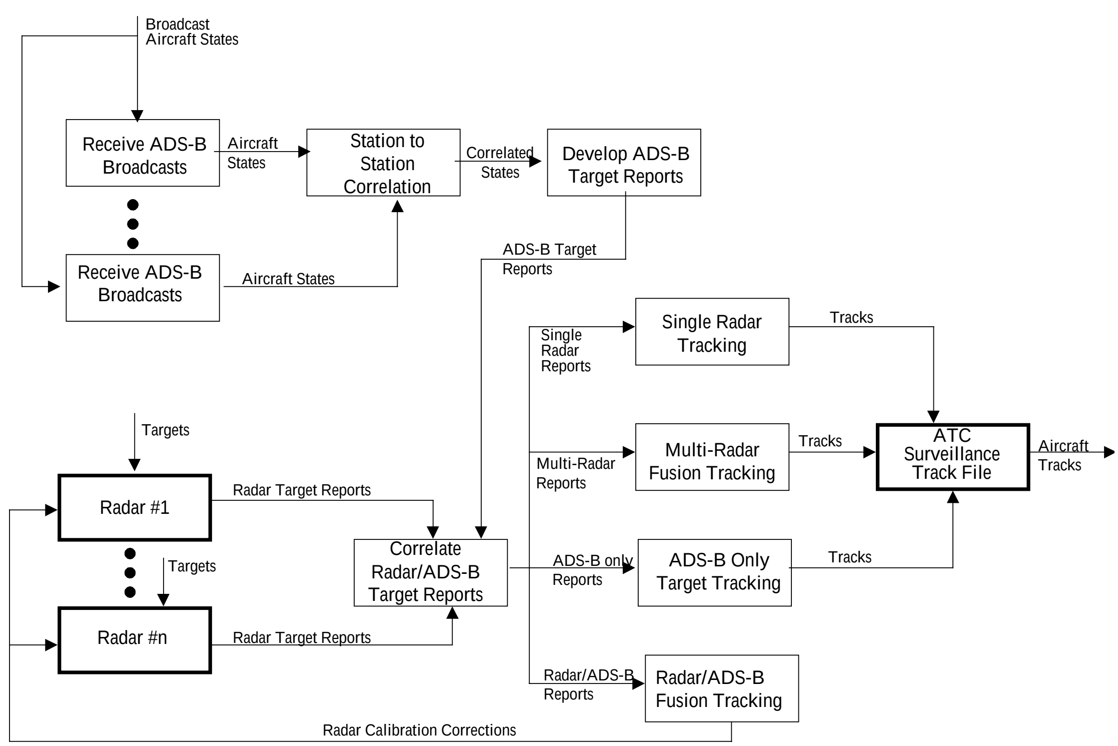


Figure 3.9.3-1 ADS-B/SS Functional Block Diagram

3.9.3.1 System Functional Relationships

The ADS-B/SS primary inputs consist of beacon radar reports from the beacon radar system and ADS-B Target reports from the ADS-B surveillance system. The beacon radar reports may be reinforced with primary radar or not. Primary radar reports are not included in this enhancement although they are processed according to the procedures used in the current surveillance processor. The upper portion of the above figure shows the process used to form the ADS-B target reports. It is likely that the ADS-B message from a given aircraft will be received by more than one ADS-B ground station. Thus, a station- to-station correlator is required in order to remove duplicate reports from the same aircraft. These correlated messages are then formed into ADS-B target reports for use by ATC this enhancement.

Radar target reports and ADS-B target reports are then correlated to determine targets under surveillance of:

- Single Radar
- Multiple Radars
- ADS-B Only
- ADS-B and Radar

Once the ADS-B/Radar Correlator makes this determination the target reports are distributed to the appropriate tracking algorithm. In the case of single radar targets, the alpha/beta tracker used in the current system is adequate but could be replaced with a more sophisticated tracker if desired. This however is not seen as necessary. In the case of a target under surveillance of multiple radars, these reports are sent to a multi-radar fusion tracker which uses the data from all radars to increase tracking accuracy and update rate on that target. For ADS-B only targets, a tracking algorithm using the ADS-B position and velocity information contained in the report is applied. Finally, for targets under ADS-B and radar surveillance simultaneously a Radar/ADS-B fusion tracker is applied. This tracker uses the radar and the ADS-B data to improve not only the tracking performance on the target but also to reduce radar bias errors through automatic calibration and to reduce registration errors between the ADS-B and the Radar systems. These later capabilities are critical since the reduction of bias errors on the radars will improve radar only target tracking and the reduction of registration errors between the two systems will allow both radar only and ADS-B targets to be more safely and efficiently treated by automated decision support tools. Registration errors could cause a reduction in surveillance performance and ATC services as compared to the current system unless they are properly addressed by this enhancement.

3.9.3.2 Interface Requirements

Examining the ADS-B/SS functional design illustrated in Figure 3.9.3-1 one observes that the major inputs to this enhancement are from the ADS-B ground stations and from the beacon radars. The output of this system provides tracks to the Automation Surveillance Track File. Several internal interfaces also exist among the functional elements of this enhancement.

3.9.3.2.1 Internal Interfaces

Internal interfaces include:

- ADS-B Station-to-station correlation to Target Report Generator - This provides the development of ADS-B target reports from the ADS-B messages
- ADS-B Target Report Generator to Radar/ADS-B Target report correlator - This provides the sorting of targets among the categories of single radar , multiple radar, ADS-B, and radar/ADS-B
- Correlator to Tracker - This provides the appropriate target categories to the proper tracker types

3.9.3.2.2 External Interfaces

External interfaces include ADS-B/SS interfaces with:

- Beacon Radar Systems - to obtain radar target reports and provide calibration parameters
- ADS-B Ground System - to obtain ADS-B target reports
- Automation Surveillance Track File - to provide the results of fusion tracking

3.9.3.3 Human Factors Considerations

There are no human factors considerations for this enhancement.

3.9.3.4 ADS-B/SS Requirements Traceability Matrices

Three aspects of requirements traceability are provided in this section. The first provides traceability between the ADS-B/ERA capabilities and the operational requirements as stated in the ATS 2005 CONOPS Narrative and the Joint Government/Industry Operational Concept. The second provides the functional allocation of the operational requirements derived from the ATS 2005 Narrative to the major ATC functions (i.e., communications, navigation, surveillance, weather, automation, maintenance and operations). The third aspect provides a recommended requirement validation methodology for each of the functional requirements identified in Section 3.9.2.

3.9.3.4.1 Capabilities to CONOPS Traceability

These operational requirements are derived from the ATS 2005 CONOPS Narrative. They have been developed based upon key word searches of the ATS 2005 Operational Needs database. The key words used in these searches were based on the ADS-B/SS capability descriptions obtained from the RTCA roadmap. Each ADS-B/SS operational requirement is related to at least one ADS-B/SS capability. Table 3.9.3.4-1 provides traceability between the ADS-B/SS capabilities and the operational requirements. In addition, the cross reference of Government/Industry Operational Concept for the Evolution of Free Flight provided as Appendix B of the Joint Government/Industry Roadmap for Free Flight Operational

Enhancements was used to provide traceability between the ADS-B/SS capabilities and the RTCA requirements. This mapping is also provided as a column in Table 3.9.3.4-1.

3.9.3.4.2 Operational to Functional Requirement Traceability

Table 3.9.3.4-2 provides the functional allocation of the set of ADS-B/SS operational requirements derived from the ATS 2005 CONOPS Narrative. It must be noted that the requirements obtained in this manner are not all directly related to the ADS-B/SS since they apply to the broader NAS. They are included however for completeness since they result from the searches associated with each ADS-B/SS capability are part of the basis for the derived functional requirements presented in Section 3.9.2.

3.9.3.4.3 Procedures for Functional Requirement Verification

Table 3.9.3.4-3 provides the list of ADS-B/SS functional requirements presented in Section 3.9.2 and the minimum test procedures to verify compliance with those functional requirements. These test procedures include the following test methods: inspection; analysis/simulation; laboratory tests; demonstrations; and, field/flight tests. For certain requirements more than one method may be indicated. Definitions of each of these verification methods are provided below.

Table 3.9.3.4-1 ADS-B/SS Capabilities and Requirements

	OPERATIONAL ENHANCEMENT Operational Capabilities	Key Words	Level 1 Narrative Operational Requirement	Joint Industry/Government CONOPS Capabilities Appendix B
9	**ADS-B to Enhance Radar and Automation Performance**			**B9**
9.1	The Terminal Automation System will fuse radar and ADS-B position data for presentation on service provider situation displays.	Position,	3.30, 4.12, 5.7, 5.18, 5.41	5.2
		Display	1.9, 3.24, 3.29, 3.30, 3.31, 3.32, 3.42, 4.18, 4.25, 4.28, 5.9.2, 5.18, 5.38, 6.15, 6.21, 6.36	
9.2	Use ADS-B to provide more accurate position and velocity information to enhance terminal automation tracker performance and reduce the false alerts declared by tactical conflict detection algorithms to accommodate a more structured flow of traffic entering terminal airspace.	Position,	3.30, 4.12, 5.7, 5.18, 5.41	4.1, 5.2
		Automation (or) decision,	1.16, 3.7, 3.11, 3.38, 3.42, 4.2, 4.5, 4.20, 4.43, 4.46, 4.49, 5.2, 5.30, 5.35, 7.33, 7.37	
		Flow	1.26, 3.12, 3.21, 4.39, 4.46, 4.55, 5.4, 7.13, 7.36	4.1
9.3	Use ADS-B to allow service providers to better provide separation services in areas with radar coverage.	Satellite,	3.30, 4.12, 5.7	5.2
		Separation,	3.28, 4.12, 4.25, 4.63, 5.6.1, 5.18, 5.30. 6.7	5.2
		Radar	5.7, 5.12, 6.7	

Table 3.9.3.4-2 ADS-B/SS Functional Allocation of Operational Requirements

Level I #	ATS 2005 Statement (Level I Need)	C	N	S	W	A	M
1.9	Replacement of Host … transition to satellite navigation …new display platforms!!Key Words: host navigation display		N			A	
1.16	Controller workload under peak traffic remains equivalent to the workload controllers absorbed in the 1990s under lighter traffic demand. This increased ATC efficiency has been achieved through the implementation of decision support systems for traffic management and control, dynamic alteration of airspace boundaries, reduced vertical separation minima, improved air/ground communications and coordination, and enhanced ground/ground coordination aids.!!Key Words: decision support systems airspace boundaries vertical separation communications coordination	C				A	
1.26	Tools and procedures are in place for frequent evaluation (up to several times a day) of the airspace structure and anticipated traffic flows, with adjustments made accordingly.	C				A	M
3.7	Surface-movement decision support systems provide real time data to the NAS-wide information system.!!Key Words: (in the same paragraph as) surface decision support			S		A	M
3.11	Surface-movement decision support systems are also an integral part of the total NAS automation system. !!Key Words: surface movement			S		A	
3.12	For departures, taxi time updates and the associated estimates included in the taxi plan are coordinated automatically with airspace automation to efficiently sequence ground traffic to match projected traffic flows aloft.!!Key Words: taxi (within 10 words of)Update or taxi Plan	C				A	
3.21	automation functions utilize these departure clearances, along with aircraft location and aircraft type, to generate taxi schedules. … departures will be spaced more efficiently than they are today, resulting in reduced taxi times and improved airborne departure traffic flows.	C		S		A	
3.24	This system's processes and displays provide complete data connectivity between the service provider, flight deck, airline operations center, ramp, airport operator, and airport emergency centers.	C				A	M
3.28	Separation assurance on the airport surface … benefits from increased information to improve situation awareness, support taxi planning, and improve ramp control to match surface movement with the departure and arrival phases of flight.!!Key Words: separation	C		S		A	
3.29	Visual cues that service providers currently rely upon are augmented with enhanced situation displays and surface detection equipment.!!Key Words: separation			S		A	

3.30	Service providers can display satellite-derived position data transmitted by selected flights upon request, while ground-based surveillance data is shared with users as a safety enhancement for preventing incursions.	C		S		A	
3.31	Situation displays are available for airborne and surface traffic, with appropriate overlaps for viewing arriving and departing traffic.	C		S		A	
3.32	The surface situation display depicts the airport and nearby airspace, with data tags for all flights and vehicles			S		A	
3.38	For departures, the decision support system incorporates departure times, aircraft type, wake turbulence criteria, and departure routes to safely and efficiently sequence aircraft to the departure threshold.!!Key Words: departure (in the same paragraph as) DSS					A	
3.42	In 2005, ramp service providers, where used, sequence and meter aircraft movement at gates and on ramps, using situation displays that interface with decision support systems and personnel in the control tower.!!Key Words: separation	C		S		A	M
4.2	Decision support systems increase the efficient use of airport assets by providing assistance in planning taxi sequences and spacing, and in the assignment of aircraft to runways.					A	
4.5	Automatic exchange of information between flight deck and ground-based decision support systems improves the accuracy and coordination of arrival trajectories.	C	N	S	W	A	
4.12	Satellite-based position data, broadcast by properly equipped aircraft, are used in cockpit traffic displays to increase the pilots' situation awareness for aircraft-to-aircraft separation. These avionics allow an increasingly frequent transfer of responsibility for separation assurance to the flight deck for some types of operations.!!Key Words: self separation!!	C	N	S		A	
4.18	disruption in departure and arrival traffic is minimized by improved weather data and displays. Available to service providers and users, these data and displays enhance safety and efficiency by disclosing weather severity and location.!!Key Words: weather	C			W	A	
4.20	Decision support systems help service providers to maintain situation awareness, identify and resolve conflicts, and sequence and space arrival traffic.!!Key Words: decision support systems –or- automation in the same paragraph as) conflicts –or- separation –or- sequence!!	C		S	W	A	
4.25	To assure aircraft separation, service providers utilize improved tools and displays.					A	
4.28	The distribution of this information by improved displays assists the service provider in maintaining situation awareness and in traffic planning.	C				A	

4.39	Improved departure flows are achieved through tools that provide more efficient airport surface operations, improved real time assessment of traffic activity in departure and en route airspace, and expanded usage of flexible routes based on RNAV, satellite navigation, and FMS.!!Key Words: departure flow	C	N	S		A	
4.43	In the final portion of the arrival phase, decision support systems facilitate the use of time-based metering to maximize airspace and airport capacity.	C		S		A	
4.46	The traffic flow service provider … receives increased assistance from decision support systems for managing arrivals and departures.!!Key Words: TM DSS!!			S		A	
4.49	service providers utilize the decision support systems to monitor traffic flows, NAS performance, and weather.	C		S	W	A	M
4.55	Arrival flows and departure queues are planned around projected times for configuration changes that cause the least traffic disruption.	C		S		A	
4.63	Augmentation systems have the accuracy, availability, integrity, and continuity necessary for precision approaches. Separation standards are set in accordance to the accuracy of the positional information.!!Key Words: precision approach		N			A	M
5.2	Improved decision support tools for conflict detection, resolution, and flow management allow increased accommodation of user-preferred trajectories, schedules, and flight sequences.!!Key Words: DSS or automation) in the same paragraph as (conflict or flow)	C		S	W	A	
5.4	The airspace structure is adjusted to meet user needs. Tools and procedures are in place for frequent evaluations of the airspace structure (probably daily), and anticipated traffic flows are accommodated by adjustments to sector boundaries.!!Key Words: airspace (in the same paragraph as) evaluation sector boundary	C		S	W	A	
5.6.1	Structured routes are the exception rather than the rule, and exist only when required to meet continuous high density, to provide for the avoidance of terrain and active SUAs, and to facilitate the transition between areas with differing separation standards.					A	M
5.7	Surveillance of all positively controlled aircraft is provided by a combination of primary and secondary radar, and the broadcast of satellite-derived position information by individual flights.!!Key Words: surveillance	C		S		A	
5.9.2	New displays are operational in all en route facilities and the service provider has access to more accurate forecasts of potential conflicts.!!Key Words: display (in the same paragraph as) conflict			S		A	
5.12	En route surveillance is accomplished through a combination of primary radar, beacon interrogation, and broadcasts of aircraft position and speed.	C	N	S		A	

5.18	Separation standards depend on the flight's equipage and the quality of the positional data, service provider displays indicate the quality of the resulting aircraft positions and the appropriate equipage information. !!Key Words: separation Standards	C		S		A	
5.30	As in the departure and arrival operations, increased decision support allows significant improvement in en route separation assurance.	C		S		A	
5.35	Decision support systems assist in conflict detection and the development of conflict resolutions.	C		S		A	
5.38	Use of paper flight strips is eliminated since decision support systems display necessary information.					A	
5.41	For VFR aircraft automatically reporting their satellite-derived positions … coupled with access to the flight's data via the NAS-wide information system, reduces the workload associated with providing traffic advisories to uncontrolled aircraft.!!Key Words: traffic advisories	C	N	S		A	M
6.7	Real time position data and continuously updated trajectory projections virtually eliminate manual control procedures in Oceanic airspace … Oceanic separation standards and procedures are derived from radar control techniques.	C		S		A	
6.15	Service providers use visual displays to monitor the traffic situation!!Key Words: display			S		A	
6.21	The oceanic service provider has a display of traffic in the oceanic airspace, ensuring separation in the same manner as in domestic airspace, although the separation criteria may be different.	C		S		A	
6.36	Service providers, aided by supporting automation and electronic visual displays, are able to acquire and view timely and reliable flight information to dynamically address necessary changes to the airspace or trajectories. !!Key Words: automation	C		S	W	A	
7.13	Automation and decision support capabilities tailored for the ATCSCC … facilitate coordination among local and national traffic flow managers to improve decision making.	C				A	M
7.33	Increased collaboration among local facilities, the ATCSCC and NAS users is augmented by decision support systems that enable a shared view of traffic and weather with all parties.	C			W	A	
7.36	Improved decision support systems help service providers visualize demand and manage the more complex traffic flows.	C		S	W	A	M
7.37	decision support systems that evaluate NAS performance in real-time enable the service provider to be more responsive and to develop more effective traffic management strategies.					A	M

Table 3.9.3.4-3 ADS-B/SS Functional Requirement and Verification Definitions

Insp	Inspection	Verification is based the determination that the system specification includes the requirement, the system was developed to include the capabilities of the requirement, and an examination of the system shows that the capabilities to meet the requirement were included. Results show that the required capability is in the system to the extent verifiable by inspection only.
A/S	Analysis / Simulation	Verification is based on analysis of the developed system capability. This analysis includes desk checking of characteristics and simulation. Operation of the system is not required. Results show that the specified capability, to the extent possible using analysis and simulation, was developed in the system in such a way the required capability is achievable.
Lab	Laboratory Test	Verification is based on operation of the system (in part or as a whole) in a laboratory environment. Some laboratory equipment may be used in place of operational equipment. Results show that specific required capabilities are achievable using the developed system (in part or as a whole) with laboratory instruments used for measurement and stimulation.
Demo	Demonstration Test	Verification is based on operation of the system (in part or as a whole) using operational equipment. Laboratory equipment is not used. Results show that the selected capability is observed using system components.
Field	Field Test	Verification is based on operation of the system using operational equipment in an operational environment. Results show that the selected capability is repeatedly demonstrable in an operational environment
Validation	Validation Test	Verification is based on operation of the system using operational equipment in an operational environment. Results of the comprehensive evaluation of thorough performance testing show that the full scope of the capability is achieved and is repeatable.

Table 3.9.3.4-4 ADS-B/SS Functional Requirement and Verification Procedures

Number	Functional Requirement	Insp	A/S	Lab	Demo	Field
9C-1	The ground-side element of ADS-B/ERA shall receive the ADS-B broadcast of aircraft states at all ADS-B ground stations within range of the broadcast.		X		X	
9C-2	The ground-side element of ADS-B/ERA shall receive all radar target reports from radars that overlap the coverage of the ADS-B system.		X	X		
9N-2	The airside element of ADS-B/ERA system shall receive its navigational position from GPS, when available.				X	X
9N-3	The navigational position information shall be able to include WAAS and LAAS satellite information, when available.			X		
9N-4	If GPS is not available, the aircraft shall use an appropriate area navigation instrument to provide an input to the airside element of the ADS-B/ERA processor and shall declare a degraded mode of operation.			X		
9S-1	ADS-B/ERA shall receive ADS-B broadcasts of aircraft state.			X	X	X
9S-2	The ADS-B ground-side element shall consist of a sufficient number of ground stations to provide coverage of the ADS-B designated airspace.		X			
9S-3	The ADS-B/ERA shall receive radar target reports from all ATC radars that have coverage of the designated airspace.		X			
9A-1	The ground-side element of ADS-B/ERA shall perform ADS-B ground station-to-station correlation of the received aircraft states from all stations within range of the broadcasting aircraft.			X		
9A-2	The ground-side element of ADS-B/ERA shall develop ADS-B target reports based on the correlated aircraft state data from one or more ADS-B ground stations.			X		
9A-3	The ADS-B/ERA shall correlate all radar and ADS-B target reports to identify those targets that are ADS-B only, ADS/B and radar, single radar only, and multiple radar.			X		
9A-4	The ADS-B/ERA shall provide tracking algorithms for each class of target, i.e., ADS-B only, ADS/B and radar, single radar only, and multiple radar.			X		
9A-5	The ADS-B/ERA shall provide all target tracks, properly identified, to the ATC .Surveillance Track File.			X	X	X
9A-6	The ADS-B/ERA shall provide fusion tracking for multi-radar targets and for ADS-B/radar targets. In the case of the ADS-B/radar targets, the ADS-B/ERA shall use the redundant information to determine a set of calibration coefficients for the appropriate radar(s).			X	X	
9OM-1	The ADS-B/ERA airside and ground-side system elements shall monitor all target report inputs to determine the integrity/reasonableness of the data.			X		
9OM-2	The ADS-B/ERA ground-side system elements shall monitor its own operational status and shall automatically report any malfunctions to the ATC system.			X		

4. NOTES

4.1 Acronyms and Abbreviations

ACID – Aircraft Identification
ADS-B - Automatic Dependent Surveillance-Broadcast
ADS-B/NRA – Automatic Dependent Surveillance-Broadcast/Non-Radar Airpspace
ADS-B/SS - Automatic Dependent Surveillance-Broadcast/Separation Standards
ARTCC – Air Route Traffic Control Center
ASD – Airport Surface Display
ASDE – Airport Surface Detection Equipment
ATC – Air Traffic Control
ATIS – Automatic Terminal Information Service
ATS – Air Traffic Services

CDTI – Cockpit Display Traffic Indicator
CFIT – Controlled Flight into Terrain
CNS – Communication, Navigation and Surveillance
CONOPS – Concept of Operations
CPDLC – Cockpit/Pilot Data Link Communication

DME – Distance Measuring Equipment

ERA/A – En Route Air-to-Air
ESA – Enhanced See and Avoid

FFP1- Free Flight Phase 1
FIS - Flight Information Services
FIS-B – Flight Information Services - Broadcast

GPS – Global Positioning Services

IFR – Instrument Flight Rules
IMC – Instrument Meteorological Conditions
ITWS - Integrated Terminal Weather System

LAAS – Local Area Augmentation System
LLWAS – Low Level Wind Shear Alerting System
LVTO – Low Visibility Terminal Operations

MASPS - Minimum Aviation System Performance Standards

NADIN - National Airspace Data Interchange Network
NAS – National Airspace System
NAS-WIS – National Airspace System-Wide Information System
NASA – National Aeronautical and Space Administration
NOTAM – Notice to Airmen

PIREPS – Pilot Reports

RTCA - Radio Technical Commission for Aeronautics
RVR – Runway Visual Range

S/AO – Surface/Approach Operations
SUA – Special User Airspace

TCAS – Traffic Collision Avoidance System
TDWR – Terminal Doppler Weather Radar
TERPS - Terminal Radar Procedures
TIS - Traffic Information Services
TIS-B – Traffic Information Services-Broadcast
TRACON – Terminal Radar Approach Control

UAT – Universal Access Transceiver

VDL – Very High Frequency Data Link
VFR – Visual Flight Rules
VHF – Very High Frequency

WAAS – Wide Area Augmentation System
WARP – Weather and Radar Processor

4.2 Definitions

Operational Requirement - A precise specification that must be met by a system in an operating environment

Functional Requirement - Allocates the operational requirements to specific functions (i.e., Communications, Navigation, Surveillance, Weather, Automation, Management)

Performance Requirement - Quantified functionality associated with the entire system and the functional elements

Surveillance Requirement - A precise surveillance specification, derived from the functional and performance requirements that must be met by a surveillance system

Functional Specification - The functional elements of a system based on the functional requirements and illustrated by functional flow charts and data interfaces